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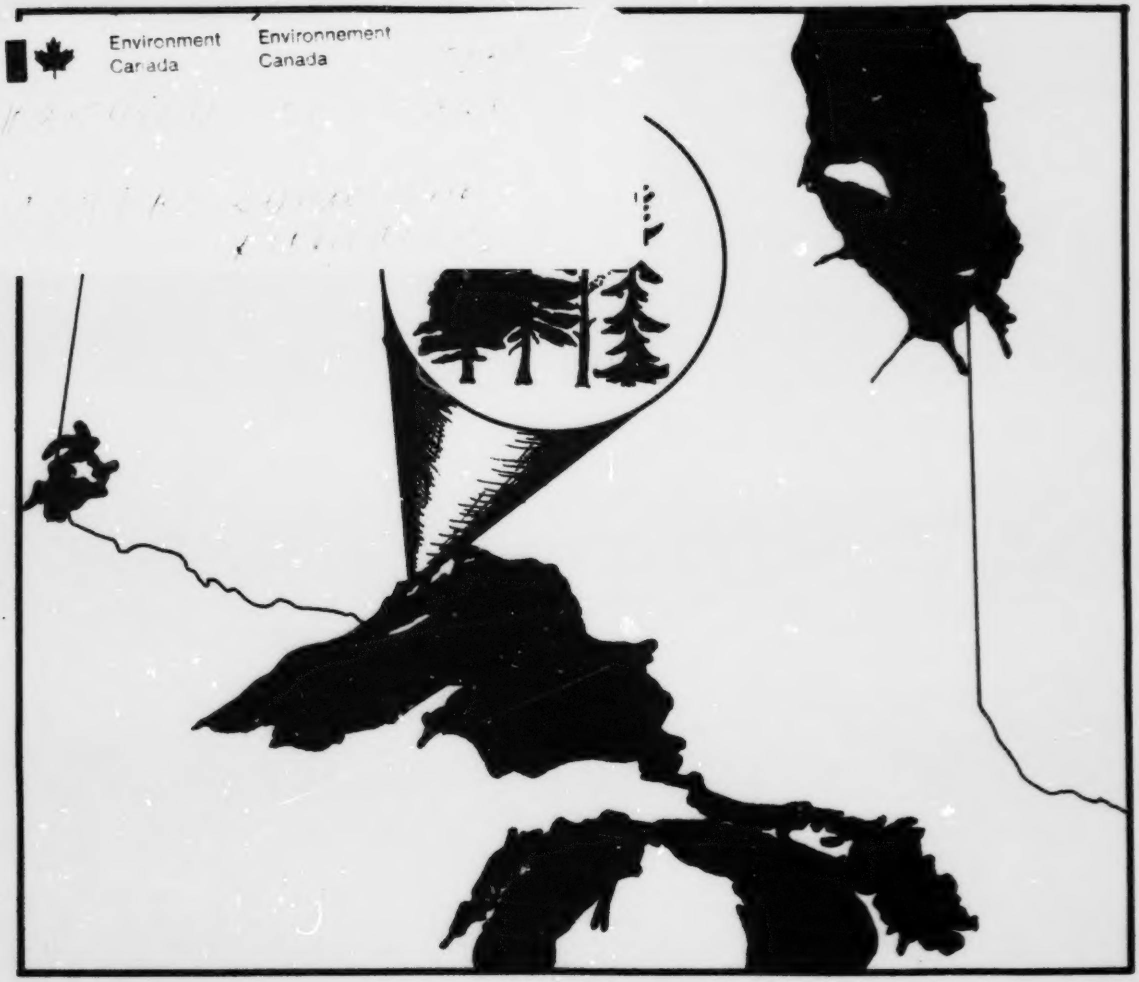
Boreal Mixedwood Symposium



Proceedings of a Symposium sponsored by
the Ontario Ministry of Natural Resources
and the Great Lakes Forest Research Centre
under the auspices of the Canada-Ontario
Joint Forestry Research Committee

5-2301/

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BOREAL MIXEDWOOD SYMPOSIUM

Proceedings of a Symposium sponsored by the
Ontario Ministry of Natural Resources
and the
Great Lakes Forest Research Centre
under the auspices of the
Canada-Ontario Joint Forestry Research Committee
Thunder Bay, Ontario
16-18 September, 1980

R. D. WHITNEY and K. M. McCLAIN, COCHAIRMEN

GREAT LAKES FOREST RESEARCH CENTRE
SAULT STE. MARIE, ONTARIO

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CANADIAN FORESTRY SERVICE
DEPARTMENT OF THE ENVIRONMENT
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FOREWORD

The Boreal Mixedwood Symposium, cosponsored by the Ontario Ministry of Natural Resources and the Great Lakes Forest Research Centre (Canadian Forestry Service), was held from 16 to 18 September, 1980 in Thunder Bay, Ontario. The symposium was the ninth in a continuing series of symposia initiated in 1972 by the Canada-Ontario Joint Forestry Research Committee (COJFRC). The main purpose of the series is to provide a forum for discussion for researchers, provincial and industrial forest managers, and educators in the field of forestry in Ontario. Forestry officials from outside the province are invited as well.

The purpose of the Boreal Mixedwood Symposium was twofold: to review current management procedures and problems in Ontario's boreal mixedwood forests[1]*, and to stimulate interest in, and improvement of, the management of this difficult and complex forest type.*

About 160 delegates were welcomed by Mr. J.H. Cayford, Acting Director General, Research and Technical Services, Canadian Forestry Service and current Chairman of COJFRC, and by Mr. G.A. McCormack, Assistant Deputy Minister for Northern Ontario, Ministry of Natural Resources. The formal program was chaired by Mr. W.K. Fullerton, Director, Forest Resources Branch, Ministry of Natural Resources.

Boreal mixedwood management deals with five major Ontario species and covers a broad range of subject areas; hence, it was obvious that not all facets of the topic could be covered in a three-day symposium. Six general areas that had not been discussed in depth in previous symposia of this series were therefore selected for broad coverage. Twenty-four papers were presented and a conscious attempt was made to introduce the ecosystem concept and to include management purposes other than fibre utilization (e.g., wildlife). The discussion which followed the papers was recorded and paraphrased and is presented at the end of each section.

A digest of each paper was circulated to delegates about six weeks before the symposium and most of the 24 papers were distributed to session chairmen before the symposium. Members of the planning committee wish to thank all authors for their cooperation in meeting deadlines.

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[1] *Defined on page 1 of these proceedings.*

The field trip on 17 September to the Fort William and Shebandowan management units was intended to demonstrate principles, practices and problems described during the indoor sessions, and to show delegates examples of conditions and management options in the boreal mixedwood forest. Delegates found the walking trail a welcome change from formal meetings.

Members of the planning committee wish to express their appreciation to staff of the Shebandowan and Fort William management units, especially Ron Calvert and Karl Latt, and Terry Casella, Bob Forslund and Gerry Page, technical staff, Northern Forest Research Unit, OMNR, Thunder Bay for organizing the field trip and for operating the recording and projection equipment during the presentation of papers. Blake MacDonald and Del Parker, who conducted the field trip, and Geoffrey Pierpoint, who provided soil and site descriptions, deserve special recognition. We also acknowledge our indebtedness to Nancy Knudsen, Northern Forest Research Unit, for her help in handling correspondence and registrations.

It is to be hoped that deliberations during the symposium not only improved our understanding of this difficult to manage section of the Boreal Forest, but also enhanced the working relationships between researchers and forest managers. We have a common goal in attempting to improve our utilization of this resource for all purposes; it is only that we approach this goal from different perspectives. Let us make a sincere attempt to complement one another's efforts in order to reach our common goal.

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INTRODUCTORY REMARKS

J.H. Cayford, Acting Director General
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Canadian Forestry Service
Department of the Environment
Ottawa, Ontario

and

G.A. McCormack, Deputy Minister
Ontario Ministry of Natural Resources
Toronto, Ontario

J.H. Cayford: "Welcome to the Boreal Mixedwood Symposium. This is, as you are all aware, one of the annual symposia of the Canada-Ontario Joint Forestry Research Committee, the organization commonly known as COJFRC. Each year through COJFRC the Ontario Ministry of Natural Resources and the Great Lakes Forest Research Centre of the Canadian Forestry Service organize a symposium. This is the seventh successive year that it has been my pleasure and privilege to make a few introductory comments at the symposium and during this period we have covered several important topics: mechanization of silviculture, black spruce, plantation establishment, white and red pine, tree improvement, and remote sensing. I think it is particularly appropriate that this year's symposium features the boreal mixedwoods. The term "mixedwoods" in itself is rather imprecise. The organizing committee have provided a definition which will be discussed by our first speaker, while the importance of the forest will be considered in a later paper.

The boreal mixedwood covers about 45-50% of the productive forest area in Ontario and provides 20-30% of the conifer harvest. I think it is fairly safe to say that the value of this forest can only increase in the future because of its relatively southerly location and because of the inherent fertility of most sites that support mixedwood forest cover. This symposium is very timely in view of the fact that boreal mixedwoods were discussed at great length at the first Ontario conference on forest regeneration which was held in the same hotel here in Thunder Bay about 2½ years ago. It is also appropriate that the man responsible for this conference, the Hon. Frank Miller, is going to address us today. In summarizing the regeneration conference Bill Fullerton and Al Peacock rated the regeneration gap in mixedwood stands as the second most important technical problem facing the Ministry, and they noted that poor utilization was one of the main factors inhibiting forest regeneration efforts. Speakers at this symposium will cover a wide range of topics: they will provide background information on the ecology and extent of the boreal mixedwood forest and will discuss fibre utilization and forest harvesting. The program will conclude with three sessions on forest management practices.

The symposium has been planned and organized by a committee representing both the provincial and federal governments and is the outcome of efforts by the COJFRC Spruce-Fir-Aspen Forest Research Committee. This is a continuing committee that has had responsibility for coordinating the boreal mixedwood forest research programs of the Great Lakes and Ontario Forest Research Centres and has published a major compendium of research needs in this forest. In this connection I would be remiss if I did not acknowledge the special contributions of Keith McClain and Roy Whitney as cochairmen of the symposium and those of Frank Lyon, Jack Basham, David Weingartner, Blake MacDonald and Ago Lehela, who were on the committee.

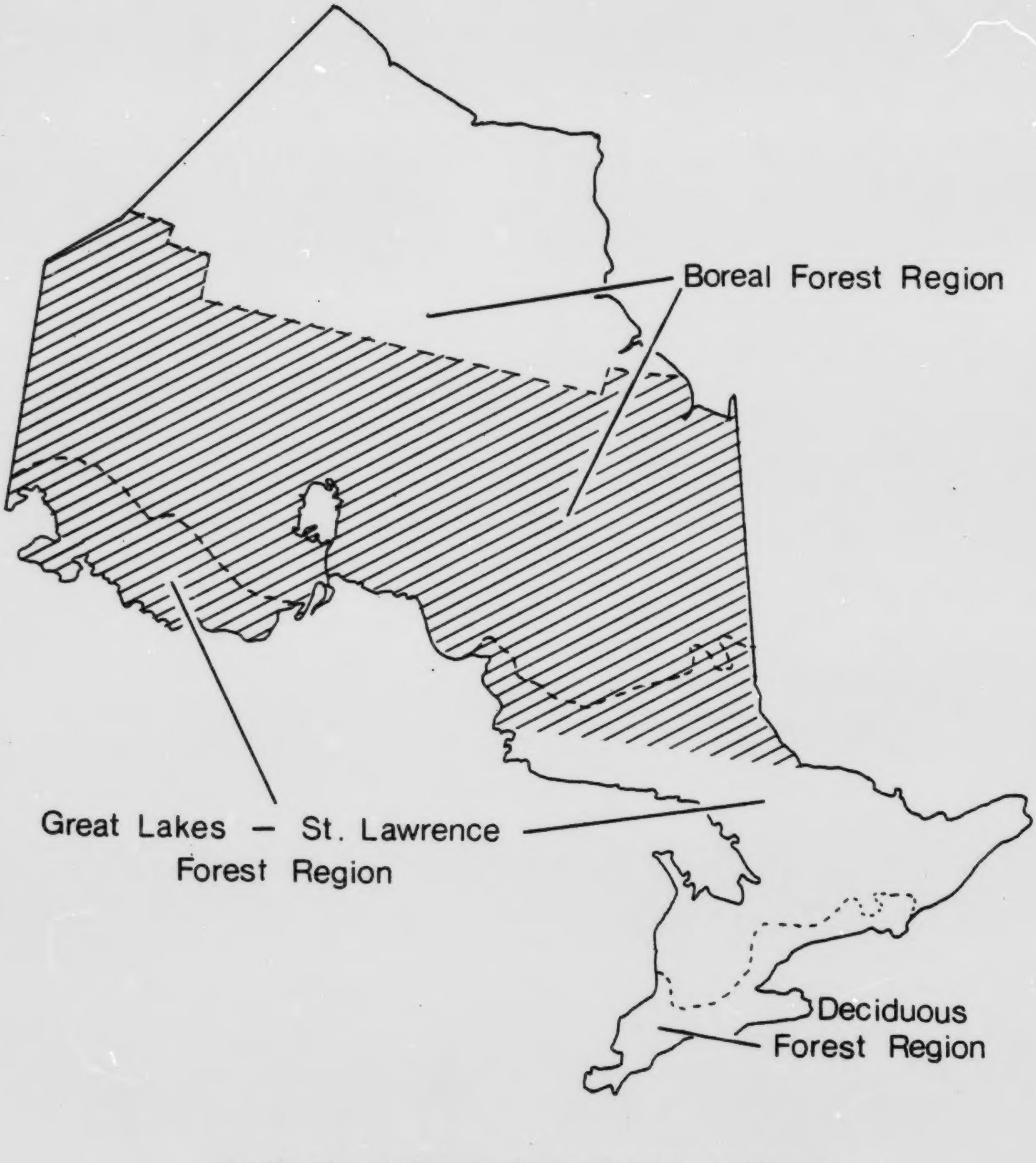
On behalf of the Canada-Ontario Joint Forestry Research Committee and the Canadian Forestry Service I would like to welcome you to the 1980 COJFRC Symposium. I would also like to extend my best wishes for the success of the meeting."

G.A. McCormack: "Ladies and gentlemen, it is a pleasure for me to welcome you to the Boreal Mixedwood Symposium here in Thunder Bay. The series of symposia begun in 1972 is one of the many positive results of the association of the Canadian Forestry Service and the Ontario Ministry of Natural Resources through the Canada-Ontario Joint Forestry Research Committee. I am pleased to see so many experts here--researchers, forest managers, industrial foresters, consulting foresters, forestry teachers, and wildlife biologists--because I am told that the boreal mixedwood forest is one of the largest and most problematic forest entities in Ontario. It is probably the least understood and most undermanaged forest in the province as well. I could have made the same statement 20 years ago when I was a unit forester, and although I know we have made progress in the management of the boreal mixedwood forest since then, it is apparent to me, after reading the digests of the papers to be presented at this symposium, that we still have a long way to go.

Jim Cayford has pointed out the economic importance of the boreal mixedwood forest, and you will be hearing shortly about its complexities as well as our successes and failures with its management. I believe that the three days devoted to this symposium will be very important to forestry in Ontario.

The members of the planning committee are to be congratulated for their efforts. I hope that you will leave, at the end of this three-day session, with new insights into the makeup and management of this complex forest, and a determination to tackle with renewed vigor the problems associated with it.

SESSION I: WHY BOREAL MIXEDWOOD MANAGEMENT?


Boreal Forest Region
Great Lakes – St. Lawrence Forest Region
Deciduous Forest Region

Distribution of boreal mixedwood forest in Ontario.

SESSION I: WHY BOREAL MIXEDWOOD MANAGEMENT?

Introduction (*F.C. Robinson*)

In this first session of the Boreal Mixedwood Symposium we will try to set the stage for the discussions by defining as precisely as possible the forest we are talking about, and stating why we think it is important.

What's in a name? I cannot get very excited about the name boreal mixedwood forest, but in the definition we must be very clear about what we include and what we exclude, so that we are all talking about the same thing. It avoids a lot of confusion.

The name is, however, part of the description. The forest used to be covered broadly by the old FRI (Forest Resources Inventory) cover types of mixedwoods and hardwoods. We had not begun managing it at that time, so no further identification seemed necessary. When we undertook studies of stand development after logging, the forest became known as the spruce-fir association. Later still, as aspen became important to us, we expanded the name to the spruce-fir-aspen association. The newest name, used in this symposium, the boreal mixedwood forest, is a reversion to something closer to the old cover types. I like the name and I hope we don't change it again.

You won't find this name, or any other, on the FRI type maps. I don't see this as a problem. The FRI stand description is for inventory; it serves this purpose well, and there is no need to change it. What we need is a name and definition to describe an association of working groups for silvicultural purposes. The boreal mixedwood forest covers a group of stands which, no matter what their present working group, have a similar potential and similar problems.

The boreal mixedwood forest is varied and complex and therefore hard to define. Even so, I believe there would be very little disagreement among us, if we were out in the forest, in deciding which stands belong and which do not. The first two papers describe the forest cover and the forest sites.

The final part of this session deals with the practical issue of dollars and cents. In fact, the real answer to the question "Why boreal mixedwood management?" and the real reason for holding this symposium can be best expressed, ultimately, in terms of dollars and cents.

We are not doing a bad job of managing the relatively pure conifer working groups, but our mixedwood forest is being converted to a much higher proportion of balsam fir and aspen.

We are not reaching our production policy targets, our land base is smaller than we had believed, and our conifer allowable cut will be shrinking at a time when we can expect the demand for long-fibre conifer wood to increase.

We can certainly practise more intensive management in our conifer stands to help overcome these problems, but there are biological, practical and economic limits. The biggest potential for increasing our forest production lies in the largely under-managed boreal mixedwood forest. If we consider the extent and the productivity of this forest, it seems obvious that the economic future of the forest industry, as far as quality, quantity and type of product it has to market are concerned, is heavily dependent on how we manage the boreal mixedwood forest. The alternative choices we have are dictated by forest conditions, but how we choose among the alternatives depends on our forest management objectives and on economic factors.

The last paper will elaborate on the importance of managing boreal mixedwoods, and the economic choices open to us.

DEFINITION AND DISTRIBUTION OF THE BOREAL MIXEDWOOD FOREST IN ONTARIO

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Northern Forest Research Unit
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In this paper the **boreal mixedwood forest** *is described, but because of its extreme variability and complexity in terms of species composition and occupation of sites, it escapes exact definition. Changes in the definition will be necessary as our knowledge of this forest association increases. It has been estimated that nearly 50% of Ontario's productive forest land lies within the* **boreal mixedwood forest** *and supports perhaps as much as 46% of Ontario's primary growing stock. Its importance to the forest economy of the province is therefore obvious.*

La présente communication donne une description de la **forêt boréale mélangée.** *Mais, en raison de l'extrême variabilité et complexité de la composition de ses peuplements et de son aire écologique, il est impossible d'en donner une définition précise. Cette définition devra être modifiée à mesure que nos connaissances en la matière s'amélioreront. On a évalué que près de 50% des terres forestières productives de la province se trouve dans la* **forêt boréale mélangée,** *et pourrait contenir jusqu'à 46% du bois de première venue en Ontario. Son importance pour l'économie forestière de la province est par conséquent évidente.*

Productive forest land in Ontario was originally inventoried and classified into cover types: coniferous, hardwood, mixedwood, and reproducing forest (Dixon 1963). The basis for classification was the number of coniferous or hardwood stems present within a stand; if more than 75% were coniferous the stand was designated a coniferous cover type. Similarly, if more than 75% of the stems present were hardwood the stand was classified as a hardwood cover type. Combinations containing less than 75% of either coniferous or hardwood stems were classified as mixedwoods.

Recent modifications to the inventory procedure involving the classification of stands according to working groups have greatly improved the manner in which silvicultural management of forest stands is carried out. Further modifications are suggested to take into account the diverse nature of mixedwood stands so that they can be treated as an entity, and managed under a mixedwood silvicultural system. In this way, successional trends leading to the development of stands of less valuable hardwood species can be avoided.

Recognition by the Spruce-Fir-Aspen Forest Research Committee[1] of the productive capacity of mixedwood stands and their associated problems led to the collation of existing information pertaining to the *boreal mixedwood forest*, definition of the problems associated with its management, and recommendations for resolving these problems (Weingartner and Basham 1979). After an in-depth consideration of forest associations containing softwoods and hardwoods it was concluded that cover types or forest associations can be appropriately defined not only on existing vegetation but also on the site occupied by the forest vegetation. This approach has been adopted by the Spruce-Fir-Aspen Forest Research Committee and, for reasons of geographical clarity, the term "*boreal mixedwood forest*" has been coined to refer specifically to the forest which I will now describe.

The *boreal mixedwood forest*, by virtue of its extreme variability and complexity in terms of species composition and occupation of sites, escapes exact definition. For reasons of expediency, and as a point from which to proceed, the Spruce-Fir-Aspen Forest Research Committee has proposed a working definition of this type in terms of *sites* that support, or could support, *good* growth of the five main component species, namely, white spruce (*Picea glauca* [Moench] Voss), black spruce (*P. mariana* [Mill.] B.S.P.), balsam fir (*Abies balsamifera* [L.] Mill.), trembling aspen (*Populus tremuloides* Michx.), and white birch (*Betula papyrifera* Marsh.). Essentially, sites excluded under this definition are wet, poorly drained lowlands (commonly supporting black spruce), dry sand plains (commonly supporting pure jack pine (*Pinus banksiana* Lamb.) or jack pine-black spruce mixtures) and excessively drained shallow soils on rocky ridges (commonly supporting jack pine and/or black spruce). Included in this broad definition are the many soils of glacial, lacustrine, or alluvial origin that are typically found along river valleys and on slopes leading to lowland depressions and lake basins. Moisture regimes vary from dry to very moist and are dependent largely on slope positions and soil texture.

It should be emphasized that the definition of the *boreal mixedwood forest* is only a working definition and will undoubtedly be altered many times to reflect increased knowledge derived from research, observation, and day-to-day forest management activities in northern Ontario.

---

[1] An appointed subcommittee of the Canada-Ontario Joint Forestry Research Committee.

Because of varied site conditions and the dynamic nature of the *boreal mixedwood forest*, species composition varies considerably throughout its range from high conifer-low hardwood to high hardwood-low conifer combinations. Within any combination, individual species can be present in or absent from the mixture; i.e., one or both of the hardwoods (aspen, birch) can occur, or one, two or three of the conifer species (balsam fir, white spruce, black spruce). Stand composition at time of harvest is the result of many factors: stand history, site productivity, seed availability, and other factors such as insects, disease and fire which influence stand establishment, composition and development.

Within the range of the *boreal mixedwood forest*, species not included in the definition can be present. Their presence is due largely to site (MacLean 1960) but also to factors previously mentioned, particularly site disturbance and seed availability.

The presence of jack pine within a typical *boreal mixedwood forest* is perhaps the best example of a variation on the definition given above. Other species that may occur are white pine (*Pinus strobus* L.), red pine (*P. resinosa* Ait.), eastern white cedar (*Thuja occidentalis* L.) and larch (*Larix laricina* [Du Roi] K. Koch). Although the occurrence of these species in the *boreal mixedwood forest* may be common and important to local forest management, they are, nonetheless, atypical components of the *boreal mixedwood forest.*

The *boreal mixedwood forest* lies within the Boreal Forest Region and the northernmost portion of the Great Lakes-St. Lawrence Forest Region (Rowe 1972) but is restricted geographically by the increasing occurrence of excluded species of the forest type (Fig. 1).

Within its range and on the basis of a recompilation of published forest inventories of the administrative districts of northern Ontario (before reorganization in 1972) as well as the northern half of the districts of Sault Ste. Marie, Sudbury and North Bay, the broad forest cover type distribution in the Boreal Forest Region and the adjacent portion of the Great Lakes-St. Lawrence Forest Region of Ontario is approximately 55% coniferous, 32% mixedwood, 7% hardwood and 6% reproducing forest (Dixon 1963). Most of the 39% composed of mixedwood and hardwood cover types falls within the definition of the *boreal mixedwood forest.* Since the 55% coniferous cover type includes stands with up to a 25% hardwood component, probably an additional 5% to 10% can be classified as *boreal mixedwood forest.* Furthermore, with the inclusion of about one-quarter of the reproducing forest, 45% to 50% of northern Ontario's productive forest land (21.3 million ha) could be classed as *boreal mixedwood forest.* In terms of the five main component species this represents 46% of the growing stock of portions of northern and central Ontario (Table 1). Indeed, the *boreal mixedwood forest* is of obvious importance to the economy of Ontario, a fact which demands that serious effort be exerted by forest managers at all levels to manage this forest type as a whole, not just by species.

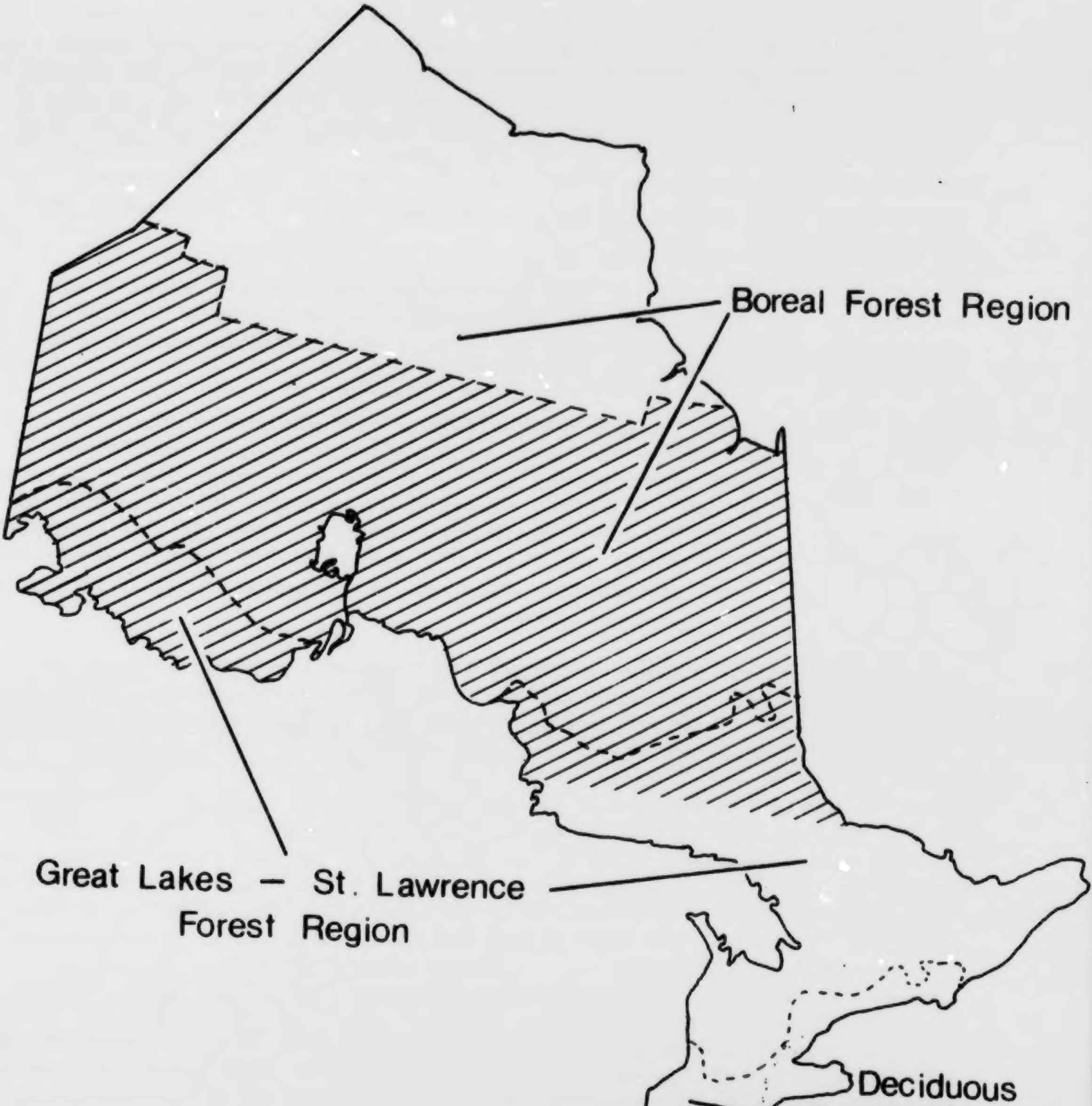
Boreal Forest Region
Great Lakes – St. Lawrence Forest Region
Deciduous Forest Region

Figure 1. Geographical distribution of the *boreal mixedwood forest* (hatched area) in northern Ontario.

Table 1. Primary growing stock of portions of northern and central Ontario by cover type (after Dixon [1963]).

	Species	EFA[a] (modified)	PEFA[b]	Total	Grand total
		---	('000 cu. ft)[c]	---	
Boreal mixedwood forest	white spruce	6,366,064	600,188	6,966,252	54,066,511
	balsam fir	7,349,853	1,075,455	8,425,308	
	poplar	22,176,503	2,710,210	24,886,713	
	white birch	12,288,111	1,500,127	13,788,238	
Conifer	black spruce	30,471,891	13,247,069	43,718,960	63,177,964
	jack pine	16,464,606	2,994,398	19,459,004	
Total					117,244,475

[a] Exploitable forest area - for all northern districts and half of each of the districts of Sault Ste. Marie, Sudbury and North Bay.

[b] Potentially exploitable forest area.

[c] 1 cu. ft = .03 cu. m.

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SITE TYPES IN THE BOREAL MIXEDWOOD FOREST

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Classification of ecosystem (coincident land and vegetation) types is discussed. A two-dimensional grid based on soil moisture and nutrient regimes is presented to aid in understanding how the boreal ecosystem types relate to each other. Soil and vegetation characteristics of three major divisions of the boreal mixedwood forest are described.

La classification des écosystèmes (végétation et sol en présence) est examinée. L'auteur présente un tableau à double entrée de l'humidité et des substances nutritives du sol pour aider à comprendre comment les différents écosystèmes de la région boréale sont reliés entre eux. Les caractéristiques du sol et de la végétation de trois grands secteurs de la forêt boréale mélangée sont décrites.

This paper deals with the site types of the boreal mixedwood forest, but first of all I would like to present a few definitions and discuss a few key features to set the scene.

A *forest site* is just a place in the forest. Now, this place or site has many characteristics. The non-living physical "land" characteristics include the type of soil material, steepness of slope, position on slope, drainage and soil moisture supply, soil nutrient supply, local climate, etc. The living vegetation which is characteristic of this place or site includes the main tree canopy, the understory trees and shrubs, and the lower plants near the ground, maybe small shrubs, herbs, mosses, ferns, etc.

We can think of the combination of vegetation and the physical land as making up an ecological system which, for brevity, we can call an "ecosystem". Quite obviously, animals are involved as well. We will restrict our view in this paper to the physical land and the coincident vegetation, but others, later in the symposium, may consider some of the animals as well.

Our entire boreal forest, therefore, is a mosaic of places or sites, each site being an ecosystem or combination of land and vegetation.

As we travel through this boreal forest mosaic, we see some places that are similar to some other places with respect to land conditions, for example. Now the land is not identical in all these places, but it is sufficiently similar that we find it useful to group all of the places into one physical land type. We can repeat this "viewing exercise", concentrating on the vegetation, and this time we find a number of places that all have similar forest stand conditions--again, not identical conditions, but sufficiently similar to allow us to group all of these places into one forest cover type.

So, *type* is a subdivision, a part of the whole range of actual conditions. Obviously, there is still a certain range of conditions within the limits of the type. From our observations of various real world situations within the limits of the type, we form a concept of the modal or "typical" condition, and we use that typical condition to describe or define the type. But we must not forget the range that exists within the type. Figure 1 will help us to understand this.

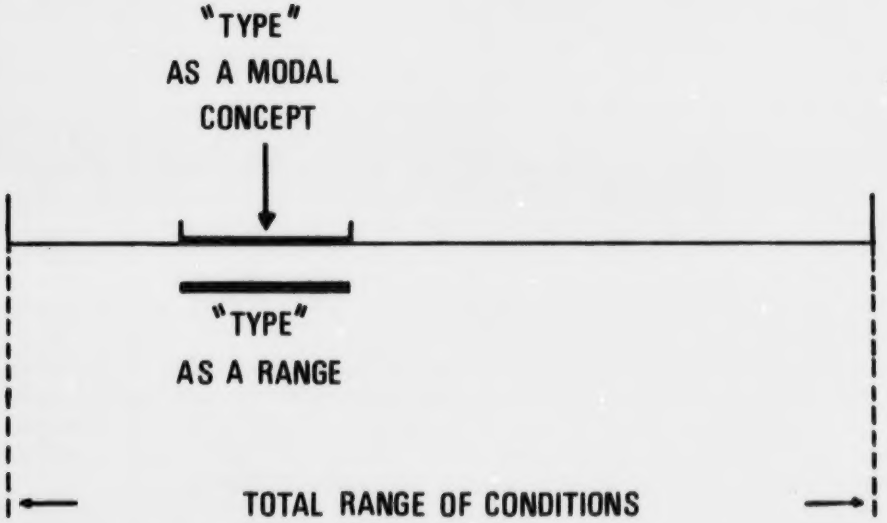


Figure 1. "Type" as a modal concept and as a range of conditions.

Why do we bother with "classification" and "types"? Simply so that we can carry useful information and experience from one situation to another. If we are making silvicultural decisions about a black spruce (*Picea mariana* [Mill.] B.S.P.) forest, we do not bother to consider our experience and knowledge in jack pine (*Pinus banksiana* Lamb.) forests--they are of a different type. We marshal and use our knowledge and experience from other black spruce forests, i.e., forests of the same type.

Returning to our travels through the boreal forest mosaic, we easily see that by considering both the land and the vegetation at each place, we can group all the places which are sufficiently similar to each other into one appropriate "ecosystem type".

In the boreal forest we find a close association between particular physical land conditions and particular vegetation populations. In a practical classification scheme for the boreal forest, the number of ecosystem types need not be large. Each ecosystem type can be identified by a few key features. *Soil moisture regime* is one key land feature. This is influenced by soil texture and structure, soil depth, topographic position, internal drainage and underground water. All sites can be placed along a continuum of soil moisture regimes from the driest site to the wettest site, and the continuum can then be divided into classes. One possibility is a four-class scale (dry, fresh, moist, wet), which can be divided further into an eleven-class scale (θ, 0, 1-------9). I will not discuss in this paper the recognition of moisture regime classes in the field, but it is not a difficult procedure as the criteria for each class are easily recognized.

Soil nutrient regime is another key land feature. This is influenced by soil texture, soil mineral composition, soil profile development (particularly the organic and upper mineral horizons), soil moisture regime and lateral seepage of drainage water. Again, the continuum from the poorest to the richest site can be divided into classes. One possibility is a five-class scale from A, the poorest, to E, the richest.

Figure 2 shows how we can make a two-dimensional soil grid by using the moisture regime scale on one axis and the nutrient regime scale on the other. This gives us a useful visual aid for discussing how the various boreal ecosystem types relate to each other, and for orienting ourselves within the boreal mixedwood forest.

Now I shall talk in more detail about the site types of the boreal mixedwood forest.

The boreal mixedwood forest lies more or less within the shaded portion of the soil grid (Fig. 2), but within this portion there is a wide range of land conditions. It is not surprising, therefore, that we find a wide range of forest stand conditions within this boreal mixedwood mosaic. Keith McClain's paper defined the boreal mixedwood forest

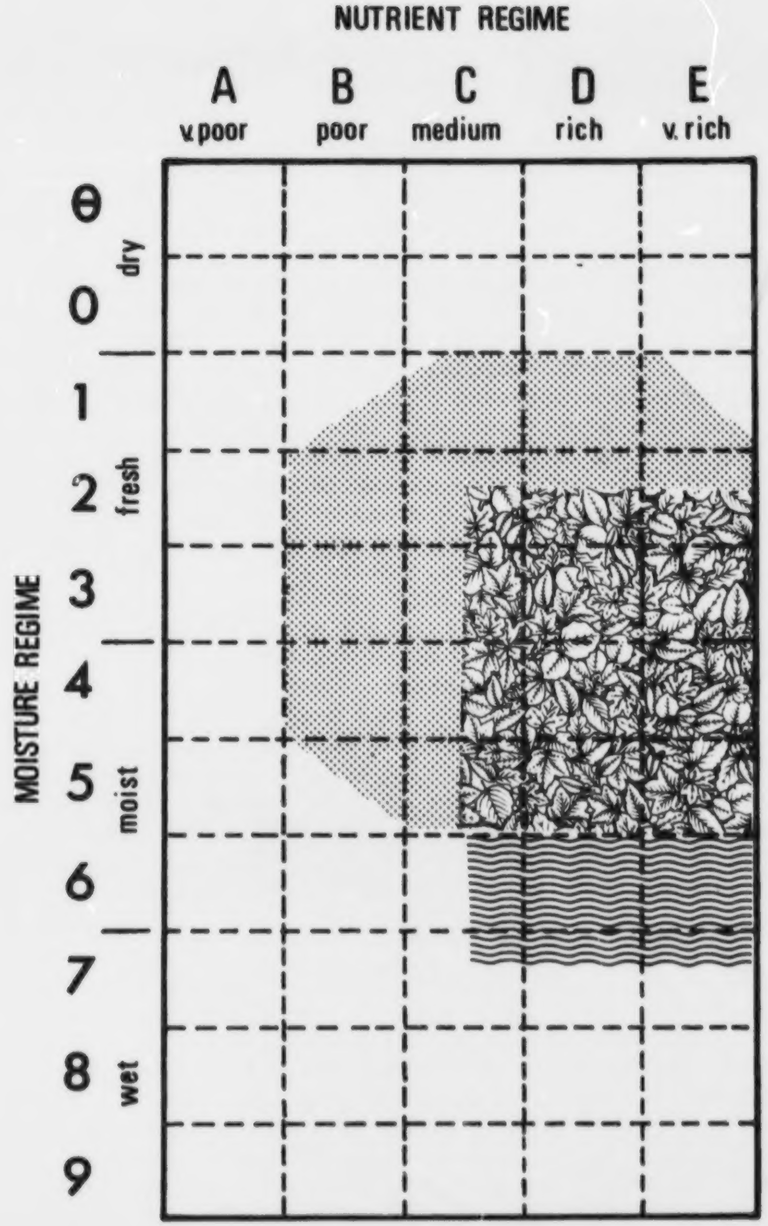
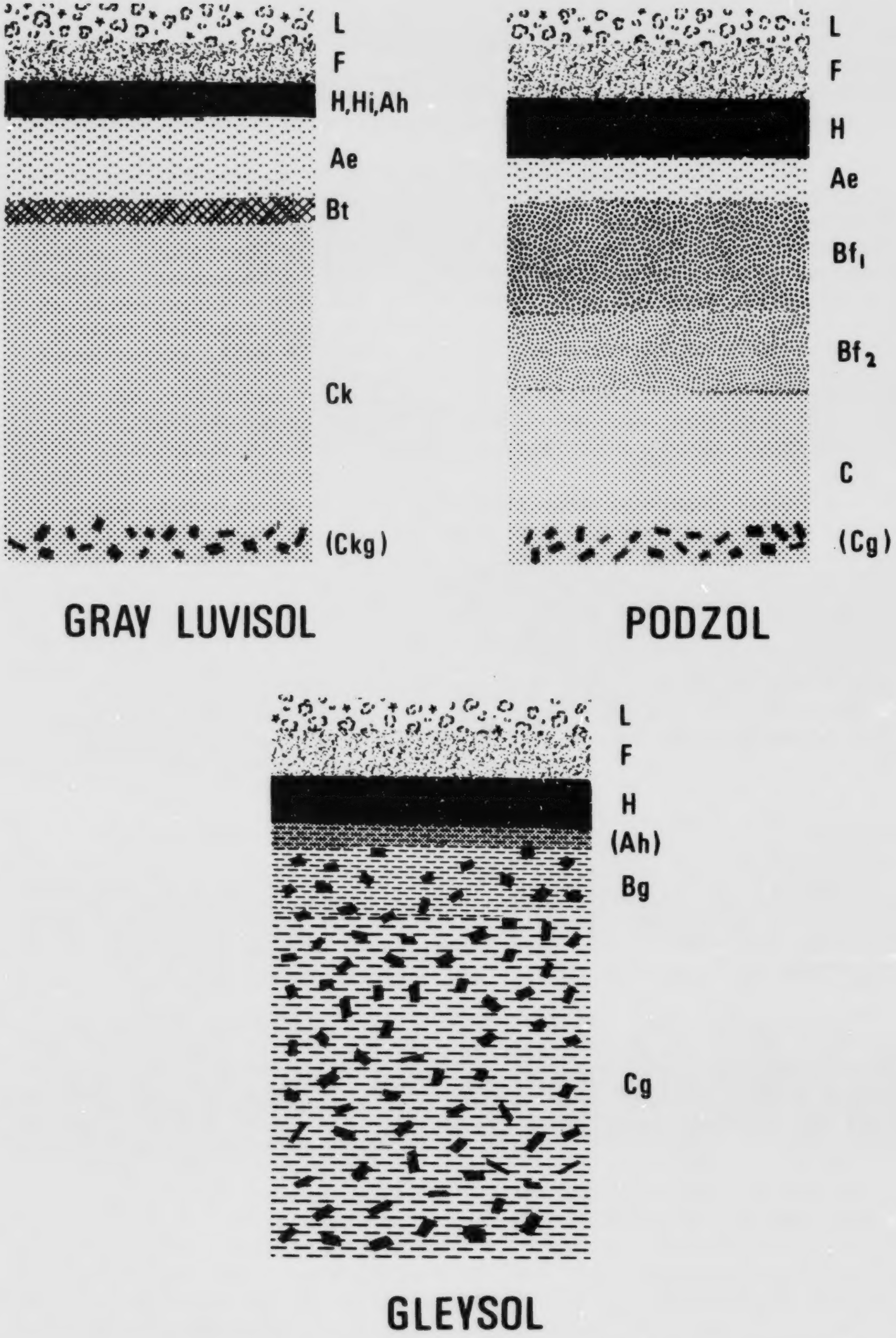

NUTRIENT REGIME
A
v. poor
B
poor
C
medium
D
rich
E
v. rich
MOISTURE REGIME
θ
0
dry
1
2
fresh
3
4
5
moist
6
7
8
wet
9

Figure 2. A soil grid based on moisture regime and nutrient regime scales. The shaded portion indicates the location of the three major divisions of the boreal mixedwood forest.

as being *not* jack pine on dry sandy soils, *not* pure black spruce on wet organic soils or very shallow soils over bedrock, and so on, and he indicated that certain trees may be absent today but the potential is there for them to develop in the next stand tomorrow.

Let us start with what we might consider to be the classical forest of white spruce (*Picea glauca* [Moench] Voss) and balsam fir (*Abies balsamea* [L.] Mill.), with possible admixtures of trembling aspen (*Populus tremuloides* Michx.) and other species. These spruce-fir-aspen forests develop most strongly on the fresh to moist, rich sites shown with "leafy" shading on the soil grid (Fig. 2). These moisture and nutrient conditions are best provided by well drained to imperfectly drained, intermediate to fine-textured soils (loams to clays). These soils are frequently calcareous, showing a reaction with hydrochloric acid in the underlying parent material (Ck). The organic litter often breaks down quite rapidly, with reasonable incorporation into the mineral soil. The soil profile development is frequently of the gray luvisol group (Fig. 3), showing a grayish leached Ae layer over a brown, clay-enriched textural B_t horizon. There may be mottling lower in the profile (Ckg) as a result of short-term seasonal saturation. Rich herb and shrub vegetation, with many species, occurs within these stands. Typical species include sarsaparilla (*Aralia nudicaulis* L.), bush honeysuckle (*Diervilla lonicera* Mill.) and big-leaf aster (*Aster macrophyllus* L.). In some places, the forest stand may contain no hardwoods and may even have a high proportion of black spruce. Jack pine, also, can be a strong component in some stands on these rich sites. In other situations, the stand may be virtually pure aspen and/or balsam poplar (*Populus balsamifera* L.). So we must be prepared to accept this substantial range of forest cover within our concept of the classical boreal mixedwood. The key to recognizing the potential of these sites to produce, in the future, high volumes of wood from species which may currently be absent lies in the use of the soil and lesser vegetation characteristics described here.

Somewhat drier or less rich sites, shown on Figure 2 by "dotted" shading, usually have fine sandy to loamy, acid soil materials, with brunisol or podzol soil profiles. Figure 3 illustrates a typical podzol profile. A brunisol profile shows a less developed B horizon than a podzol and may have no obvious Ae horizon. These sites show slightly lower rates of production and fewer ground vegetation species, but still have, often, a heavy shrub layer, particularly of mountain maple (*Acer spicatum* Lam.), with herbs and various mosses. Litter decomposition may be slower, with less incorporation into the mineral soil. Within this portion of the boreal mixedwood forest, the poorest nutrient cycling condition is probably that associated with a black spruce cover and a Schreber's feather moss (*Pleurozium schreberi* [Brid.] Mitt.) forest floor. We believe that an increase in the presence of step moss (*Hylocomium splendens* [Hedw.] B.S.G.) and, then, shaggy moss (*Rhytidiadelphus triquetrus* [Hedw.] Warnst.) indicates an increase in nutrient availability.


L
F
H,Hi,Ah
Ae
Bt
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(Ckg)
GRAY LUVISOL
L
F
H
Ae
Bf$_1$
Bf$_2$
C
(Cg)
PODZOL
L
F
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(Ah)
Bg
Cg
GLEYSOL

Figure 3. Schematics of typical soil profiles within the boreal mixedwood forest.

In both sectors of the boreal mixedwood forest discussed above, *Sphagnum* mosses enter into the vegetation on the moister sites. There is a change of *Sphagnum* species along the nutrient gradient, and this is being investigated now, as I shall mention shortly.

Finally, the seepage-enriched, very moist to somewhat wet sites complete the mosaic of the boreal mixedwood forest. These are shown on Figure 2 by "wavy" shading. Here again, various mixtures of nearly all the boreal tree species can occur. Black spruce is plentiful. Eastern white cedar (*Thuja occidentalis* L.) is very often a component. Vigorous shrub, herb, fern and moss layers flourish, with a large number of species being present. Typically, a reasonably well humified organic layer, some 30 cm thick, lies on top of a gleysolic soil, as indicated in Figure 3.

ACKNOWLEDGMENT

A forest ecosystem classification program is currently being conducted within the Northern Region of the Ontario Ministry of Natural Resources. The purpose is to study the various combinations of land and vegetation that make up the boreal forest, to find out more about the relationships between the land and the vegetation, to develop a practical classification of ecosystem types for forest management, to provide some evaluation and interpretation of the types for forest management, to conduct some mapping programs in order to demonstrate the distribution of these ecosystems in the landscape, and to develop some practical aids for the forestry staff to use in identifying these ecosystems in the field.

This is a cooperative program between Ontario and the federal government. As well as myself we have Keith Jones of the Ontario Institute of Pedology in Guelph, John Jeglum of the Great Lakes Forest Research Centre in Sault Ste. Marie, Greg Wickware of the Lands Directorate in Burlington, and Kent Virgo of OMNR's Northern Region in Kapuskasing. The program has been administered by Mike Innes (now of Abitibi-Price Inc.) and Tom Rudolph of the Northern Region.

Although my name appears on this paper, all of the people mentioned above should be given credit for contributing to our understanding of the ecosystem types of the boreal forest. As our program progresses during the next year or two, that understanding will be enlarged and will be passed on to all of you.

SOME THOUGHTS ON THE ECONOMICS OF BOREAL MIXEDWOOD MANAGEMENT

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Availability of markets, control of spruce budworm and competing vegetation, and joint-use conflicts all must be considered in developing a management strategy for the boreal mixedwood forest. Despite the cost involved, the potential for high productivity offers a strong argument for intensive management.

Pour établir une stratégie d'aménagement de la forêt boréale mélangée, il convient de tenir compte à la fois des possibilités de marchés, de la lutte contre la Tordeuse et la végétation concurrente ainsi que des incompatibilités qu'entraîne l'utilisation commune de la forêt. En dépit des coûts que cela comporte, les possibilités d'une productivité élevée constituent un argument de taille pour son aménagement intensif.

The boreal mixedwood forest type as defined for this symposium forms a significant proportion of Ontario's forest real estate. It has been suggested that from 45 to 50% of the forest cover falls within this type (Weingartner and Basham 1979). If we apply our definition of the boreal mixedwood forest type to the Ontario Forest Resources Inventory (Dixon 1963) it appears that 30% of the coniferous growing stock and most of the hardwood growing stock in the boreal forest region are found in the mixedwood type. While there are no published figures on the harvest exclusive to either the boreal region or the mixedwood types, the size of the area and volume of growing stock suggest that the annual harvest from the mixedwood forest could be as much as 3 million cubic metres of softwood and 1.4 million cubic metres of hardwood, or about 26% of the total harvest from crown lands.

The area covered by the mixedwood type and the volumes harvested from these sites have made the boreal mixedwood forest an important element in the forest resource base of Ontario. However, there is some question as to just how important it will be in the future, and more specifically how much of the province's silvicultural budget should be invested in the type.

It is safe to assume that a greater volume of hardwood will be harvested in the future than was the case in the past. However, the potential yield of softwoods is questionable. The extent to which the mixedwood forest type serves as a source of softwoods depends upon how much of the silviculture budget is invested in producing softwoods on mixedwood sites. One can speculate that if the mixedwood sites are not managed for conifers, over time the softwood component will become relatively smaller. If this is the case, one has to resolve the question of whether or not to produce conifers on the mixedwood sites at the expense of natural hardwood regeneration. As well, there is the question of whether or not to produce conifers on mixedwood sites as opposed to other forest sites. Hence, there are two factors to consider in determining the fate of mixedwood sites as far as the production of conifers is concerned: the advisability of managing for conifers as opposed to hardwoods, and the selection of sites to devote to conifers.

The case for managing mixedwood sites for hardwoods is argued on the basis of relative abundance, ease of production, and a growing demand for these species. Our ultimate goal should be the utilization of hardwoods up to and beyond the currently available supply. However, the question arises as to just how much of the silviculture budget should be devoted to hardwoods in the boreal region, and how much should be devoted to softwoods. The use of mixedwood sites to produce hardwoods is inevitable. Nature will see to that. The maintenance or enhancement of the conifer component in the mixedwood type is another question. Generally speaking, a management strategy which reduces the softwood component of the forest will result in a forest base which is less valuable than one with a larger conifer content. I believe that the mixedwood forest type has to be considered conifer ground, and to convert a large portion of it to hardwoods is a dangerous economic game.

In terms of export markets for Canadian-made forest products, the demand is for conifer-based paper, pulp, and lumber. There is little indication that these markets can be satisfied with hardwood-based products, although the hardwood content may be increased. The current increase in demand for hardwoods is not a sign of a decrease in demand for softwoods. It is a sign of the relative scarcity of softwoods. We should not be deluded into thinking that we can simply replace a conifer-based industry with one based on hardwoods. In terms of markets, that would be a whole new ball game. The only rationale for converting to hardwoods would be that the cost of producing softwoods had become too high to yield a return on one's investment.

Given a preference for conifer production on mixedwood sites, one still must consider whether the mixedwood site is worth investing in. A silvicultural management strategy for softwoods cannot be based on a single cover type. It is necessary to look at the forest as a production unit, with different cover types having different potentials for producing wood. The trick is to use one's silvicultural budget to produce the most product for the least cost. The choice of product should be based upon perceptions of demand and the ability to deliver at a cost lower than anticipated revenues.

It is within this general scenario that one must consider the mixedwood forest option. First of all it is necessary to decide whether one is prepared to manage a complex forest rather than, or as well as, forest types which are somewhat simpler to deal with, but perhaps less productive, at least in a biological sense. This decision will be based upon the perceived demand for conifers both in absolute terms and in comparison with the demand for hardwoods, and a perception of the relative net advantages offered by the mixedwood sites over alternative sites on which conifers can be produced.

The arguments in favor of managing the mixedwood forest type for conifers are two:

1) The sites are probably the most fertile in the boreal forest and hence, of all sites available, offer the greatest potential for producing high per hectare yields. High yields not only pay for the cost of production but also result in a concentration of volumes on a smaller area. This reduces harvesting costs and further enhances the value of the crop.

2) The mixedwood forest on average tends to be located closer to mills and established communities than does the pure conifer forest, especially the current reserves. Therefore, there is potential for lower delivered wood costs--a major consideration in the economics of forest management.

Balanced against these potential advantages are some rather formidable problems in growing conifers in the mixedwood forest:

1) Until now, the utilization of the hardwood component has been low, with the result that a large amount of material has been left on the site and, consequently, the cost of site preparation has been prohibitive. If these sites are to produce a new conifer crop which is comparable to or better than the original crop, this problem must be resolved. To say that better utilization is the answer if you do not have markets for hardwoods is foolish. The cost of removing underutilized species has to be borne either by the silviculturist or by the logger. In terms of Ontario's forest economy, it is a charge against the mixedwood forest. The best that can be hoped for is greater commercial utilization of hardwoods. Short of this, there must be an accommodation between the logger and silviculturist to minimize the cost of the utilization problem.

2) The inherent productivity of the mixedwood forest also means that other vegetation is a problem and this has to be controlled if one is going to take advantage of the site's potential to produce softwoods. This is a cost to be charged against the mixedwood type.

3) The mixedwood forest is the home of white spruce, balsam fir and the spruce budworm. If funds are to be invested in the mixedwood forest, this forest should be protected from the spruce budworm.

4) Everybody and his moose likes the mixedwood forest as a habitat or a playground. This means that joint-use conflicts will probably pose more problems for fibre production on the mixedwood real estate than in other areas.

All of these points must be considered in the development of a management strategy for the mixedwood forest. While the list of costs is long, the potential of the mixedwood forest in terms of site productivity offers a very strong argument for intensive management. Intensive management will entail spending a lot of money to produce a lot of wood. As far as producing conifers in the mixedwood type is concerned, you can count on spending a lot of money. The real question is, can you count on producing a lot of wood? I believe that that is what the *why* in "Why Boreal Mixedwood Management?" is all about.

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Discussion

K.M. McClain: There's one thing that bears repeating at this point: the boreal mixedwood forest is very difficult to describe. Our research working group knows what it is and appreciates its diversity but to describe it adequately is difficult *because of* this diversity. In my presentation, I offered a working definition only of the boreal mixedwood forest--a definition that provides a starting point but one that we hope to improve, refine, or change, if necessary. During the next session we will find that this definition is open to various interpretations and has different degrees of significance for each of us.

M. Innes: Mr. Ketcheson intimated that we will have to be prepared to invest more money in regeneration. We've seen this coming during the last few years, as costs have risen steadily. Mr. Ketcheson, how do we convince the mill owners and politicians that higher costs cannot be avoided, and that we're going to have to balance them off against some greater good to the economy? What is being done in this respect in other parts of the world where the problem surfaced before it did in Canada?

D.E. Ketcheson: You're going to have to demonstrate that you can generate a lot of economic activity and that there's some return on your investment in forestry. If you can show that forestry is a sound investment you won't have any problem when you compete for dollars. If you can't show this, sooner or later someone is going to say "That's enough".

M. Innes: All right, but don't forget, we were fortunate enough to be able to start with fairly cheap wood. Now forestry is a major industry in the province, and many communities have benefited greatly from it. Can we not write off some of the higher costs of wood as an investment in the economy of these communities?

D.E. Ketcheson: There is a tremendous social cost involved when the industry winds down, but I believe you can look back only so far; the argument that failure to manage the forest will be more costly, in the long run, than managing it is valid only to a point. I think you have to demonstrate that you can produce something. Someone may decide that he can do a better job of supporting Kapuskasing by putting up a steel mill there, especially if he has the kind of subsidies that forest management has. I think there are options in the economy, and we can't assume that the resources we have cannot be put to better use, however painful the transition may be. Ultimately, it is up to the foresters and the forest industry to demonstrate that they are a productive element of our society; otherwise, all the eloquence in the world won't save it.

F.C. Robinson: Before going on to the next question, I would like to say that I have found the board members and analysts of the management agreement program quite optimistic about this issue. They are not too worried about putting additional money into programs as long as they see some results. They want to be assured that more acres are being regenerated.

R. Galloway: Jack pine was mentioned as part of the boreal mixedwood forest, then dismissed. I would like Geof Pierpoint or Keith McClain to describe the procedure that was followed in arriving at the definition and in excluding jack pine.

K.M. McClain: The exclusion of jack pine from the definition of the boreal mixedwood forest illustrates one of the inconsistencies of this forest type. Jack pine grows well on drier sand flats and occurs more often there than it does on sites generally occupied by balsam fir, black spruce, white spruce and the other two components--birch and aspen. In some parts of the boreal mixedwood forest, because of stand history, seed availability and other factors, jack pine can comprise almost the entire stand. But it's not the typical forest association for the mixedwood complex that we're talking about today. It is important that jack pine be managed wherever it occurs, but within the boreal mixedwood forest, management favors the five component species, singly or in combination, when they represent the majority of the standing timber. A similar situation exists in a transition zone between a mixedwood site and a lowland swamp. There the border is indistinct and black spruce naturally grades into the upland site, but in terms of frequency of occurrence in the mixedwood stand, it decreases. It is in the lower transition zone that black spruce is excluded from the definition of the boreal mixedwood forest.

G. Pierpoint: I do not dismiss jack pine at all from the boreal mixedwood forest. I mentioned, as you will recall, that jack pine can be a very strong component of this forest type, depending on the situation with which the forest manager is faced. Much of what I said referred primarily to the eastern part of the province, and the further west you go the more important jack pine becomes. However, even in the east I think we should realize that jack pine can be a very important and a very profitable component of the boreal mixedwood forest. As I said earlier, we must be prepared to accept almost any of the boreal species in the boreal mixedwood forest and work with what we find in our particular management unit.

M. Roberge: My question is for Geof Pierpoint. When you mentioned three particular soils as the most productive, was that for mixedwood stands or coniferous stands? Also, if you believe that the trend is toward more coniferous stands, then on clay soils, drainage patterns and nutrient contents will change and sites may become less productive.

G. Pierpoint: If I have interpreted your question correctly, you are talking about a variety of vegetation types and clay soils in which there is a fairly high hardwood component and good nutrient cycling. Also, you infer that where there is a higher conifer component there is perhaps less nutrient cycling and a decrease in productivity. I think this is true in most cases, and should be kept in mind. I mentioned that nutrient cycling is perhaps slowest on black spruce feather moss sites, and consequently, these sites are somewhat lower in productivity. I think we should be trying to develop conditions which promote better nutrient cycling, e.g., a better breakdown of organic materials and better incorporation of them into the profile. Yes, your observation is valid.

J. Nolan: Doug Ketcheson, you mentioned that the boreal mixedwood forest covers 45% to 50% of the productive forest area in Ontario. I thought that would apply to the total productive area in the province, i.e., both private and Crown lands, but you went on to say it provides 20% to 30% of the conifer harvest and 100% of the hardwood harvest. Do you mean 45% to 50% of the productive forest area on private and Crown lands or just Crown land?

D.E. Ketcheson: Just Crown land.

J. Nolan: This question is directed to Keith McClain or Geof Pierpoint. What role do pure white birch stands play in your definition of the boreal mixedwood forest?

G. Pierpoint: I'd like to elaborate a little on white birch for the record. I mentioned that the recognition of soil, site and ground vegetation characteristics is a key to determining the potential of the site to produce species that are not present, and that the recognition of soil and site characteristics is a key to determining the role of white birch in the boreal mixedwood forest. We find pure white birch stands growing on dry soils--dry sandy soils, coarse textured soils--which we would not consider for boreal mixedwood management but we also find stands where there are higher proportions of white birch on richer, moister sites, and these certainly should be considered for boreal mixedwood management. I'm not sure what the basic relationships are between white birch and soil conditions. Where you have finer textured soils, although you do get white birch, you find that aspen is a little more competitive and you're not likely to get pure white birch stands. There is generally a relationship between white birch and coarser textured soils across the province. The key is to look at the soil conditions along with the white birch and to interpret the significance of the white birch in relation to the boreal mixedwood in the light of what the soil conditions tell us.

D. Rae: I've a question for Doug Ketcheson. Although it was mentioned earlier there are only two types of people--those who work in the boreal forest and those who do not--in your digest you noted that the boreal mixedwood forest produces 100% of the hardwood forest. As one who works in southern Ontario, I would question that. Along with the tolerant hardwoods in southern Ontario, there must be a fair amount of poplar and white birch produced in areas that are not boreal mixedwood sites.

D.E. Ketcheson: My figures generally referred to the boreal area and I'm somewhat remiss in not making that clear in the written document.

D. Rae: Do you consider, then, that poplar and white birch are produced only in the boreal mixedwood areas?

K.M. McClain: Hardwood certainly is produced outside the boreal mixedwood forest. Within the area that I described as mixedwood there are sites and situations that would not necessarily fall within the definition of the boreal mixedwood, but would still produce poplar and white birch, though on a different productive scale than in the boreal mixedwood. Nevertheless, harvesting may occur in these stands.

F.C. Robinson: I don't think there is any suggestion that the species that grow in the boreal mixedwood wouldn't grow well outside; certainly black spruce is a species which grows elsewhere. This is a definition of a group of particular stands, particular working groups, for silvicultural purposes.

C.D. McInnes: Perhaps Doug Ketcheson's message has to do with natural history, and is as true for wildlife as it is for forestry. The message is that the frontier has gone beyond the borders of boreal mixedwoods in Ontario. It used to be that we had great uncut forests and virgin moose herds out there and all we had to do was go out and get it, but those days are gone. We have also, I think, as a society, built up expectations which the second growth forest cannot meet. Are you saying that we should be trying to lower our expectations?

D.E. Ketcheson: I think the ball game has changed. Certainly this is true as far as wood supply and wildlife are concerned. Whether or not you have to adjust your expectations depends on what you can do with your resources. If you cannot reproduce a forest supply or a moose supply for the future with the kind of resources you have or are likely to get, I think you'll have to try and change people's expectations. I don't know anything about moose management or forest management, but I'm quite optimistic that the business of growing wood is just starting and I would suspect that Ontario will grow a lot more wood in the future than it cut in the past. I don't think we will necessarily have to lower our expectations; we may just have to change our approach to the problem of wood supply.

M. Innes: On the one hand we are led to believe that we will be able to trade off certain social benefits for higher profits in the forest industry. On the other hand we are told that if we don't come out on the right end of the financial stick the industry is going to be in trouble. In my opinion, as far as wood supply and perhaps moose supply are concerned, we are facing costs comparable to those elsewhere in the world, and we will soon have to compete with other countries just as we do for manufactured goods. If we do not, we will go under, as Doug has pointed out. We can't be content with "social tradeoffs", and in any case, I think they are few and far between. We must develop cheaper operating methods on the most productive sites or our forest industry will be in serious trouble.

C.D. McInnes: Doug, the business of expectations is a matter of how you define things. I sincerely hope we can produce more wood and more moose on our land, but I think the current expectation, which is based on a lot of history, is that we can produce that wood and those moose cheaply, and I'm not sure that we can.

G.R. Bloomfield: I think that Doug Ketcheson made an excellent point when he said that we must increase utilization of underutilized hardwoods, and that, to do this, we need a great deal of capital investment from industry and research money from government. What bothers me is that industry *has* been investing in hardwood regeneration, but government has been spraying this hardwood regeneration with herbicides, and replanting the area with conifers. What happens to industry's investment in mills and factories when the so-called underutilized species run out? How can we justify gearing up to use these species when the land is being converted to conifer?

D.E. Ketcheson: Well, I don't think we're going to run out of hardwoods. It's my impression that hardwoods are a part of the boreal mixedwood forest, and in spite of all, they're thriving in it. You may have a hardwood supply problem in Thunder Bay, but not in Ontario as a whole, nor will you in the foreseeable future. As far as MacMillan-Bloedel is concerned, it would be interesting to see, if they had to choose between all their softwood operations and all of their hardwood operations, which they would select.

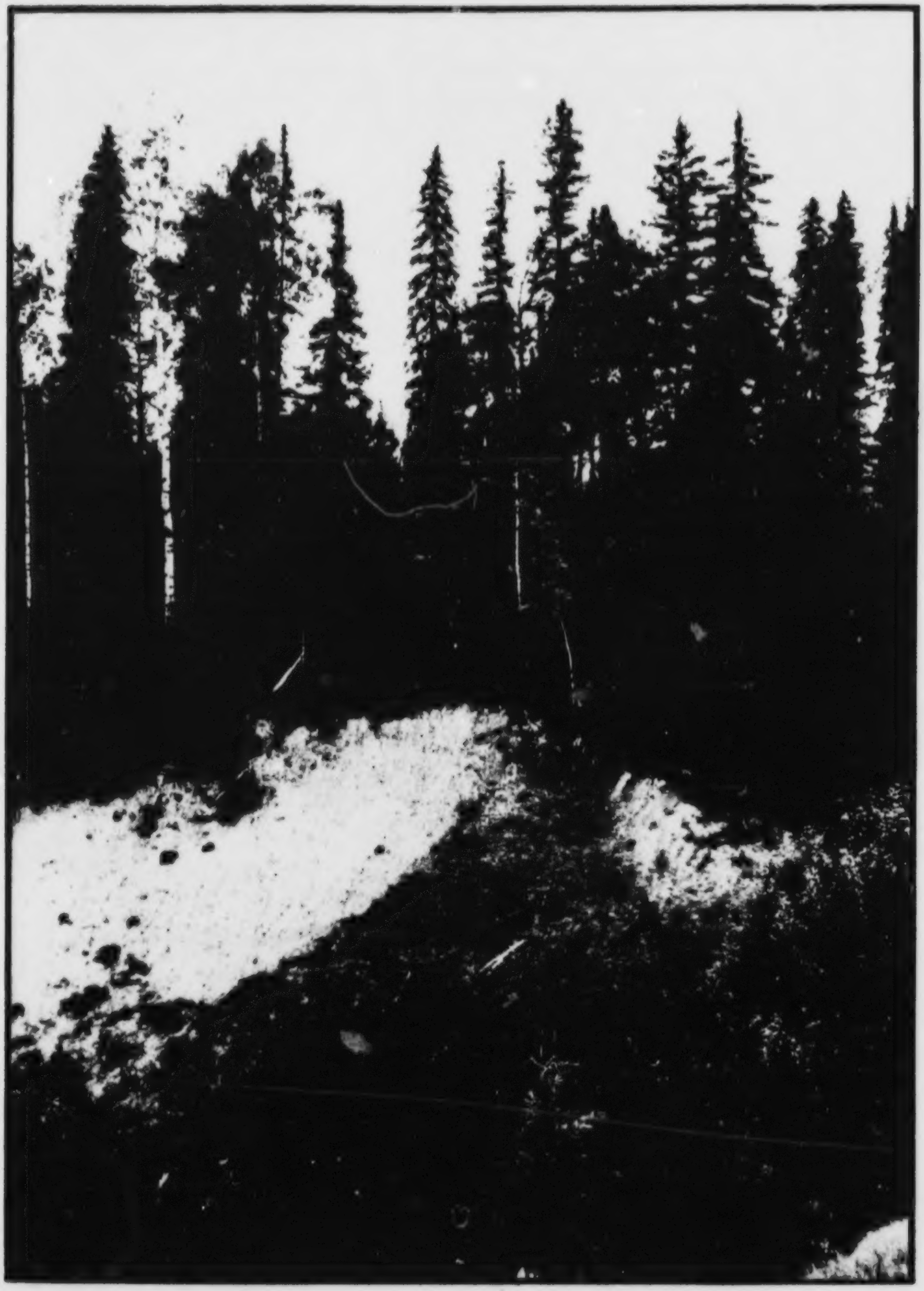
F.C. Robinson: You're right, Doug, but perhaps you didn't go far enough. I believe that, before long, we will see these conifers we've planted overtopped by the hardwoods in spite of all our spray work, and we will still end up with a lot of hardwood, so I'm not concerned about possible hardwood shortages.

V.G. Smith: We've heard about the ecosystem, classification and general description of the mixedwood stands in terms of their species composition, and we've been told that it's going to cost us more money to manage these lands. I'd be very interested to know just how productive these mixedwood forest lands are, particularly in comparison with other stands such as black spruce. If we do grow poplar in these areas can we expect twice the productivity we might expect on a poor site? What about volumes of jack pine? We believe that jack pine grows very well in mixedwood stands, as far as height and volume of individual trees and pole quality are concerned, but have we any evidence of this? Have we any hard data to support our beliefs?

G. Pierpoint: I can't provide much quantitative information at this stage. I think we can say with confidence that the very fresh to moist rich and very rich sites which I showed you on the ecosystem grid are the most productive. I suspect that, because of the nature of the mixedwood stands we have been harvesting and the limited uses to which we have been putting the wood, we are not in a position to understand fully the productivity of those stands. We can take measurements of individual trees and volumes that have been harvested and that sort of thing, but we still won't know how productive these sites might be if they were properly managed and utilized. I don't want to stick out my neck and suggest that they would produce twice as much wood as a dry sand plain, for example, or a somewhat wet organic soil, but it wouldn't surprise me if they did. Maybe someone with more experience in that field would like to try to answer this question.

A.G. Gordon: There is no question that the mixedwood sites will produce more biomass than any other land type we have in the boreal forest. When you speak of volume it's a little more complex because in the past we have looked at usable volumes in terms of organic matter production. Nevertheless, a silvicultural system would have to be developed to convert that organic matter production to usable stem production. I think Geof make reference to that.

SESSION II: THE BOREAL MIXEDWOOD FOREST ECOSYSTEM



Representative boreal mixedwood stand on glacial till in Limestone Lake area of northern Ontario.

SESSION II: THE BOREAL MIXEDWOOD FOREST ECOSYSTEM

Introduction (*R.J. Day*)

The boreal mixedwood forest is more diverse in species composition and stand structure than any other element of the boreal forest. In Session II the definition of boreal mixedwood forest given by the Meeting Committee is questioned and the boreal mixedwood forest is redefined as a complex *stratified mixture* of boreal hardwoods and softwoods, including jack pine.

The long-term role of fire and its evolutionary importance in molding the autecological behavior of the principal species found in the boreal mixedwood forest are described. Historical evidence is presented suggesting that fire has been the principal ecological factor responsible for the destruction and re-initiation of boreal mixedwood forest in its present range for 10,000 years. The evolution of serotinous (jack pine) and semi-serotinous (black spruce) cones, suckering of roots (aspens) and stump sprouting (birch, hazel, mountain maple) all suggest that boreal mixedwood forest species have been subjected to fire pressure for millions of years during the Pleistocene era.

The influence of repetitive fire on the composition, stand structure and successional development of boreal mixedwood stands and on their physiochemical environment, insect and disease interactions, and wildlife habitat is described. It is suggested that, if wildfire is excluded, the boreal mixedwood forest will lose its character, vigor and both its floral and its faunal diversity. In simple forestry terms, the exclusion of fire will cause the boreal mixedwood forest to degenerate into thickets of shrub hardwood dominated by balsam fir.

In terms of stand dynamics the boreal mixedwood forest is a fire-initiated, stratified, successional mixture with commercially valuable pioneers and less valuable, late successional species. As long as the historic fire pressure of 75± 50 years was maintained the boreal mixedwood forest remained a healthy element of the boreal forest. With the development of effective fire prevention and control measures at the end of World War II, fire was, for the most part, eliminated as a threat to this forest and was replaced by extensive logging of the valuable pioneer species.

As logging generally removes the pioneer dominants and exposes less valuable, late successional species, most cutovers are now stocked with low-value fir and hardwoods. Although reproduction after logging is far from satisfactory when compared with reproduction after wildfire, some future harvesting will be possible.

The need for an effective program of silviculture to provide the ecological conditions for reproduction of commercially valuable tree species is urgent. It is probable that improved silvicultural methods in the boreal mixedwood forest will follow improved utilization of low-value and non-commercial species.

FOREST DYNAMICS IN THE BOREAL MIXEDWOOD

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The boreal mixedwood forest is redefined as a successional mosaic *of stratified mixed stands of disturbance origin. The effect of long-term exclusion of fire is discussed. A plea is made for a 'let-burn' policy in parks and improved silviculture for maintaining the productivity of the boreal mixedwood forest.*

La forêt mélangée boréale est redéfinie en tant que mosaïque *successionnelle de peuplements mélangés stratifiés originant d'une perturbation. L'effet de l'exclusion à long terme de tout incendie est discuté. Un appel est lancé en faveur de la politique du "laisser-brûler" dans les parcs et d'une sylviculture améliorée en vue de maintenir la productivité de la forêt mélangée boréale.*

INTRODUCTION

The boreal mixedwood forest is a complex and enigmatic component of the boreal forest (Rowe 1972). According to Rowe, mixedwoods are common in almost all sections of the boreal forest except the lowlands south and east of Hudson Bay. As Rowe's descriptions of the composition of mixedwoods in the boreal forest are varied, let us first examine his definition of the boreal forest:

> ".... The white and the black spruces are characteristic species; other conifers are tamarack which is absent only in the far northwest, balsam fir and jack pine prominent in the eastern and central portions, and alpine fir and lodgepole pine in the extreme western and northwestern parts. *Although the forests are primarily coniferous, there is a general admixture of broadleaved trees such as white birch and its varieties, trembling aspen and balsam poplar*; the latter two species playing an important

> part in the central and south-central portions, particularly in the zone of transition to the prairie. In turn, the proportion of black spruce and tamarack rises northward, and with increasingly rigorous climatic and soil conditions the closed forest gives way to the subarctic open lichen-woodland which finally merges into tundra. *In the east a considerable intermixture of species from the Great Lakes-St. Lawrence forest such as eastern white and red pines, yellow birch, sugar maple, black ash, and eastern white cedar occurs.*" [italics not in the original]

To attempt to discuss the dynamics of 'boreal mixedwoods' after reading Rowe's definition is a difficult task, and it is obvious that the subject must be confined to a consideration of forest dynamics in one or more of the 45 forest sections of the Boreal Forest Region described by Rowe (1972). For this reason the B9 (Superior) and B11 (Upper English River) sections of the boreal forest have been used as a basis for this paper. These were chosen because they are well known to the authors and because they both support boreal mixedwood forest similar to that defined by the members of the Boreal Mixedwood Forest Symposium Committee as:

> "upland sites that can support growth of balsam fir, black spruce, white spruce, trembling aspen, or white birch in pure stands or in general mixtures of these species. Poorly drained lowlands (generally supporting black spruce), sand plains (generally supporting jack pine or jack pine-black spruce mixtures), and excessively drained shallow soils on rocky sites (generally supporting jack pine and/or black spruce) are excluded."

As the type of boreal mixedwood forest defined above is almost always found on upland ground moraine and on terminal moraine landforms, mixedwood may occupy up to a third of the land in the B9 and B11 sections at some time in the successional cycle. The problem with all designations of boreal mixedwood stands is that the mixtures are usually described according to the relative volume or abundance of their component species without any consideration of their stage in forest succession, or whether they are integral (horizontally arranged) or stratified (vertically arranged). The key to understanding the exact nature of boreal mixedwood stands is to study their fire history, the autecology of their component species, and the nature of the dynamic changes that take place during forest succession. For simplification, only the principal tree and shrub species that occupy the upland mixedwood sites in Ontario will be discussed in this paper. Abbreviations for all species are according to Day (1967) (see also Armson and Sadreika 1979).

Hardwoods	Softwoods
1. *Populus tremuloides* (POt), trembling aspen	1. *Pinus banksiana* Lamb. (PNb), jack pine
2. *Betula papyrifera* Marsh. (Bpa), white birch	2. *Picea mariana* (Mill.) B.S.P. (PIm), black spruce
3. *Corylus cornuta* (CLc), beaked hazel	3. *Picea glauca* (Moench) Voss (PIg), white spruce
4. *Acer spicatum* (ACsp), mountain maple	4. *Abies balsamea* L. (ABb), balsam fir

As the species in the above list are arranged in order of their position in forest succession and their tolerance (1 = intolerant pioneer to 4 = tolerant late-successional) it is now possible to rearrange the conventional description of mixedwood on the basis of integral composition so that successional stage and stratification are considered. For example, the mixture described by Rowe as Bpa - PIg - PIm - ABb - POt on till slopes in the B9 could become:

a) Upper layer - pioneer dominants	POt > Bpa
b) Middle layer - successional species	PIg > PIm
c) Lower layer - late-successional species	ABb

THE AUTECOLOGY OF MIXEDWOOD SPECIES

Before it is possible to discuss forest dynamics and the successional behavior of stands in the boreal mixedwood forest, it is essential to understand the autecological behavior of the principal species listed above. The autecologies of the principal hardwoods are summarized in Table 1, those of the principal softwoods in Table 2.

THE BOREAL MIXEDWOOD FOREST MOSAIC

The boreal mixedwood forest is composed of stands that vary in age, species composition and structure. The autecology of the principal species and an analysis of the periodicity and range of wildfire provide important clues for understanding the boreal mixedwood forest mosaic.

Lightning- and man-caused wildfires in the boreal forest have been well documented (Kayll 1968, Heinselman 1971, Scotter, 1972, Rowe and Scotter 1973). Rowe (1972) summarizes the subject as follows:

Table 1. Autecology of hardwoods.

Ecological attribute	1) Trembling aspen	2) White birch	3) Beaked hazel	4) Mountain maple
Favored LAND FORMS and SOIL TYPES	*Ground moraine* - fresh medium to deep loamy till. *Lacustrine* - well aerated silts and clays.	*Ground and terminal moraine* - dry to fresh, shallow to deep, sandy and loamy till, shallow sandy till over bedrock.	*Ground moraine* - moist to fresh, medium to deep, loamy till. *Lacustrine* - well and moderately aerated fresh to moist silts and clays.	*Ground moraine* - fresh, shallow to deep, sandy loam till. *Lacustrine* - well and moderately aerated fresh to moist silts and clays.
SUCCESSION and TOLERANCE	*Pioneer* - colonizing rapidly and very profusely after fire (much less so after windthrow) from root sprouts. *Very intolerant* - unable to compete with CLc, ACsp or ABb in late succession.	*Pioneer* - colonizing rapidly and profusely after fire or windthrow from seed and sprouts. *Very intolerant* - unable to compete with CLc, ACsp or ABb in late succession.	*Successional* - colonizing the understory as the pioneer species declines. *Moderately to very tolerant* - may dominate the understory preventing the reproduction of POt, Bpa, PNb and PIm.	*Successional* - colonizing the understory as the pioneer species declines. *Moderately to very tolerant* - can dominate the understory with CLc excluding the reproduction of POt, Bpa, PNb and PIm.
BEHAVIOR in FIRE	*Inflammable* - but owing to thin bark invariably girdled.	*Very flammable* - girdled because of thin, highly inflammable bark.	*Inflammable* - girdled at the root collar by ground fire and killed by hot fire.	*Inflammable* - girdled at the root collar by ground fire and killed by hot fire.
REPRODUCTION and ESTABLISHMENT	Puts out profuse root sprouts or, less commonly, reproduces from seed after fire. Root sprouts grow 1 to 2 m per year for 5 years, dominating the stand early and whipping most competitors.	Abundant seedlings and sprouts from the root collar after fire. Seedlings grow 0.1 m and sprouts 0.8 m the first year. Dominates and whips most competitors but not POt on good soils.	Sporadic burn survivors sprout from the root collar. Sprouts reach 0.25 to 0.5 m the first year. Seed and seedlings delayed for 3 to 4 years, so most hazel colonize the understory.	Intermittent burn survivors sprout from the root collar. Sprouts reach 0.3 to 0.75 m in height the first year. Seed is soon produced rapidly again, propagating this species in the understory.
GROWTH and DEVELOPMENT	A short-lived, very productive species. The CAI[a] (gross) of Site Class II aspen peaks at 7.0 m^3/ha. On an optimum rotation of 60 to 65 yr the MAI[b] is 5.2 m^3/ha/yr.	A very short-lived, fairly productive species. The CAI[a] (gross) of Site Class II birch peaks at 4.8 m^3/ha. On an optimum rotation of 45 to 50 years the MAI[b] is 3.0 m^3/ha/yr.	Not a productive species. A multistemmed nut-bearing shrub that may live for more than 50 years and may reach 3 m in height.	Not a productive species. It has been shown to reach a height of 7 to 8 m and to produce 2 to 4 m^2 of basal area per hectare when well developed (Vincent 1953).

[a] CAI - Current annual increment.

[b] MAI - Mean annual increment.

Table 2. Autecology of softwoods.

Ecological attribute	1) Jack pine	2) Black spruce	3) White spruce	4) Balsam fir
Favored LAND FORMS and SOIL TYPES	*Ground and terminal moraine and outwash plains* - dry to fresh, shallow to deep, sandy loams and sands.	*Ground moraine* - moist to fresh, shallow to medium depth, loamy till. *Lacustrine* - moist to overmoist, shallow to deep silts and clays.	*Ground and terminal moraine* - fresh or moist, water-receiving, moderately deep to deep sandy loams and loams.	*All glacial land forms* - remarkable tolerance of soil moisture and soil type. It grows best on deep, fresh to moist sandy loams or loams.
SUCCESSION and TOLERANCE	*Pioneer* - colonizing rapidly and very profusely after fire (only on humps after windthrow) from millions of seed stored in serotinous cones. *Very intolerant* - reproduces only in the open; unable to reproduce in or withstand suppression beneath the canopy of other species.	*Pioneer* - colonizing soon after fire. Its abundance depends on the amount of seed cast from seed stored in semi-serotinous cones and soil surface moisture after seedcast. *Intolerant* - usually reproduces only in the open or the shade of the dead stand after fire.	*Pioneer and successional* - generally colonizing with greatest abundance soon after fire, but able to continue colonizing the understory in openings at any time. It is not usually abundant after fire because its mother trees are sporadic and the cones are non-serotinous. *Moderately tolerant* - reproduces both in the open and beneath the canopy.	*Late successional* - rare initially after fire because both the non-serotinous seed and seed-bearers are destroyed by fire. Rare burn survivors slowly reinitiate new generations of fir in the understory so that the species gradually becomes very abundant in almost all stands. *Very tolerant* - reproduces beneath almost all species except CLc and ACsp.
BEHAVIOR in FIRE	*Inflammable* - usually killed, rarely only girdled or scorched by fire because of thin bark and resinous foliage. Heat opens the cones and up to 5 million seeds/ha are released.	*Inflammable* - usually killed, very rarely girdled or scorched by fire because of thin bark and resinous foliage. Heat opens the cones and up to 1.25 million seeds/ha are released.	*Inflammable* - because of thin bark and resinous foliage, it is usually killed when young. Its fire resistance increases slightly as height increases and the bark thickens. Seed from non-serotinous cones is burned by the fire.	*Very inflammable* - because of very thin, very resinous bark and foliage it burns explosively. As the cones are resinous when they are immature and fall apart when mature, all seed is consumed by fire.
REPRODUCTION and ESTABLISHMENT	Up to 500,000 seedlings/ha may become established after fire. These average 0.05, 0.2 and 0.45 m at the 1st, 2nd and 3rd growing seasons. Can compete with POt and BPa pioneers.	Abundant seedlings after fire provided there is adequate seed and suitable conditions for germination. These average 0.02, 0.07 and 0.15 m at the 1st, 2nd and 3rd growing seasons. Cannot compete with POt and Bpa pioneers.	Sporadic seedlings after fire. These average 0.03, 0.1 and 0.25 m at the 1st, 2nd and 3rd growing seasons. These are particularly susceptible to late spring frost but can tolerate competition from other species.	Initially sporadic seedlings after fire. As the seedling population develops more seedlings become established in the understory. Can compete with all species except tolerant shrubs, CLc and Acsp.
GROWTH AND DEVELOPMENT	A short-lived productive species. The CAI[a] (gross) of Site Class II jack pine peaks at 5.0 m^3/ha. At an optimum rotation of 40 to 45 years the MAI[b] is only 3.7 m^3/ha/yr.	An intermediate-lived extremely productive species. The CAI[a] (gross) of Site Class IA peaks at 9.0 m^3/ha. At an optimum rotation of 50 to 55 years the MAI[b] is 5.4 m^3/ha/yr.	A long-lived potentially productive species. As it does not grow in pure stands because of poor establishment and problems with late spring frost, growth data are rare. It probably grows better than black spruce.	A short-lived fairly productive species. It is less productive in the mixedwood forest than in eastern Canada because it is subject to stem rot at an early age. It may grow as well as black spruce up to 30 years.

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[a] CAI - Current annual increment.

[b] MAI - Mean annual increment.

> "The Boreal Forest in North America owes much of its floristic and faunistic diversity to periodic fires ignited by lightning and man since he appeared on the scene. The indirect effects of burnings in vegetation and soils, and recent direct observations of fires are reviewed [*in Rowe's paper*]. Fire is shown to exert a significant effect on vegetational composition, on soil chemical properties and thermal regime, and on animal populations through the particular *mosaic* of habitats created. In turn, fire itself is influenced by the nature of the geographic landscape ecosystems according to their surface forms, accumulations of organic materials and susceptibility to drought. It is concluded that fire should be viewed as a normal ecological process in the boreal forest...."

The effect of fire in boreal mixedwoods may be slightly less pronounced (Woods and Day 1976a, 1977a,b) than in pure coniferous forest (Day and Woods 1977, Woods and Day 1977c,d) because ignition in the former is more difficult and there are fewer highly inflammable species in some successional stages. Consequently, the average fire rotation of 75 years proposed by Swain (1973) and confirmed by Woods and Day (1976a and 1977a) for the unmanaged forests of Quetico Park may be a realistic approximation of the average frequency of forest fire before the advent of effective fire protection after World War II. The effect of periodic wildfire, approximately every 75 years ± 50 years, will be to create a *mosaic* of even-aged stands that vary from small to large according to the size of the initiating fire. The exact nature of the pioneer forest established on any single patch in the mosaic will depend on a range of factors which include the following:

1. Quality of the land: Shallow soils will be more severely affected by wildfire than deep soils. Deep soils will retain and protect root systems, and resuckering and resprouting will occur.

2. Nature of the burned over stand: This may affect the severity of the wildfire and dictate whether the fire is a severe crown fire or a ground fire. Trees and root systems surviving the wildfire are often the source of the new pioneers, especially after extensive fires.

3. Severity of the burn: A severe wildfire generating sufficient heat to kill stumps, root systems, seedbearing mother trees and seed in serotinous cones may lead to a complete change in species composition, whereas a light ground fire or a fire through the understory may merely induce understory replacement or a natural thinning in the present stand.

FOREST DYNAMICS IN THE BOREAL MIXEDWOOD

With a fire rotation that rarely exeeds 75 ± 50 or at most 125 years, it is not possible for pioneer and successional stands to develop to the late-successional or climax forest stages. This is especially the case in boreal mixedwoods because the slower growing pioneers, black spruce and white spruce, are often suppressed initially by more vigorous pioneer species such as aspen, jack pine and white birch. As many of the pioneer species live 100-150 years or more, a boreal mixedwood forest usually develops into a stratified mixture with the following layers:

Upper layer:	intolerant, fast growing, pioneer species, POt, Bpa and PNb
Middle layer:	moderately tolerant, suppressed, pioneer species, PIm, PIg
Lower layer:	tolerant, suppressed, successional species, ABb, CLc and ACsp

As the upper layer becomes decadent, the middle layer is released. This process begins about 45 to 75 years after the initiating wildfire, depending on the fertility of the site. With the decline of the upper layer, the middle layer is released and in time it assumes a dominant position over the lower layers. As both the spruces are long-lived and may dominate for 150 to 200 years on good sites, the lower layer usually does not assume dominance but remains an understory until the wildfire recycles the stand and initiates another patch in the mosaic.

Figure 1 shows the typical development of a boreal mixedwood stand at its normal maximum growth (about 75 years of age). The pioneer species still dominate the upper layer, with the abundance of aspen> birch> black spruce> white spruce> jack pine. Balsam fir seedlings, which are more abundant than either beaked hazel or mountain maple seedlings, are beginning to dominate the understory as the aspen canopy declines. The exact composition of the pioneer species in boreal mixedwood forest at 75 years will depend on the ecological factors that were active when it reproduced after wildfire.

1. Hot wildfire. The suckering potential of aspen is minimal but seedling-origin aspen are present. Most seedbearers are damaged or killed.

   birch> black spruce> jack pine> aspen = white spruce

2. Moderate wildfire. The suckering potential of aspen is high and most serotinous species are able to cast seed.

   aspen> black spruce> birch> jack pine> white spruce

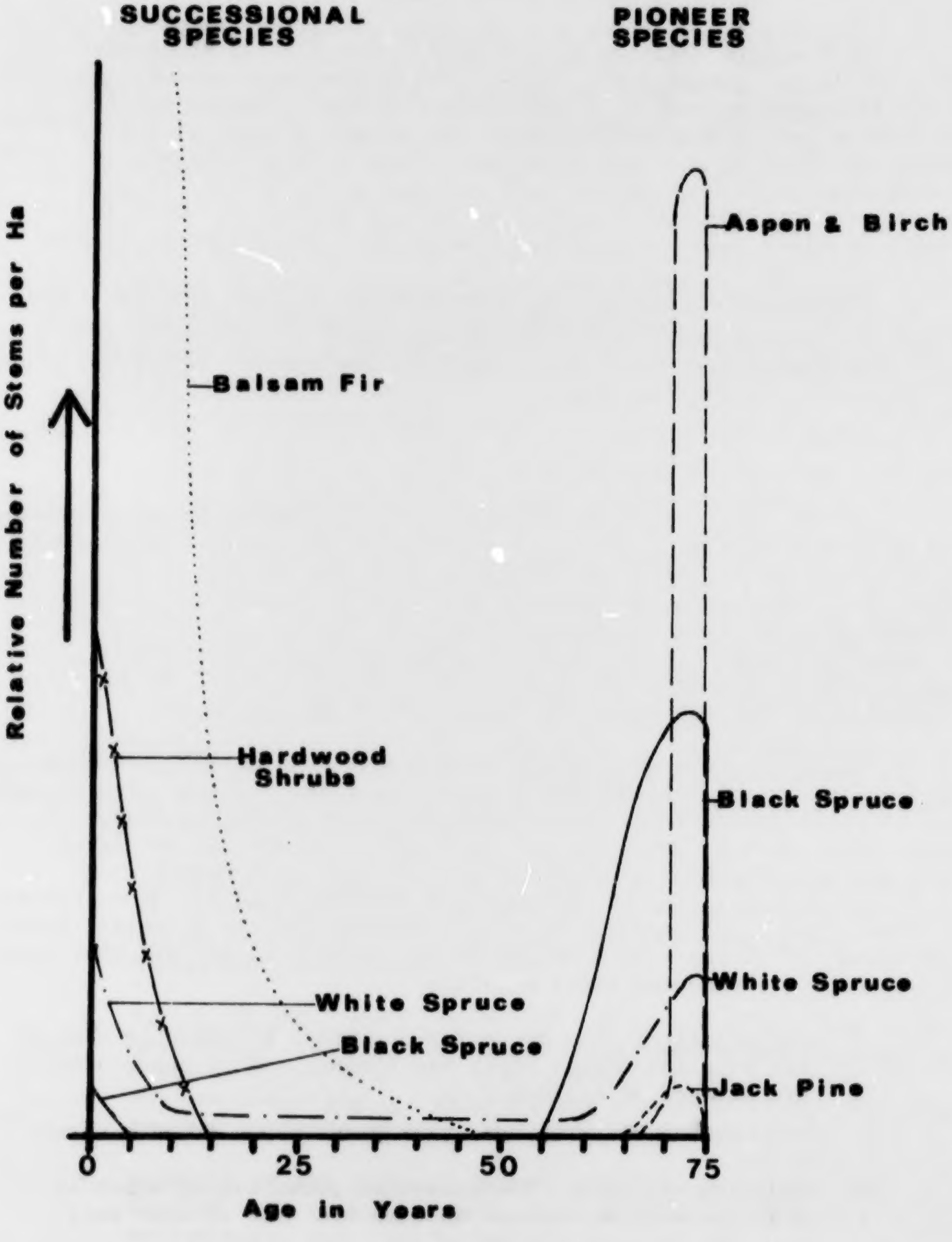

Figure 1. The age-class structure of a typical boreal mixedwood forest stand 75 years after wildfire.

3. Cool wildfire. (ground and understory burned) The more fire-resistant overstory dominants remain intact but the balsam fir is consumed and the hardwoods are girdled.

   white spruce> black spruce> aspen> birch = jack pine> balsam fir

It is not possible in this paper to describe all the combinations of species that make up the stratified mixtures in the boreal mixedwood forest. The only way to understand the boreal mixedwood forest is to learn the autecology of the species it contains and to evaluate each element of the mosaic individually.

Figure 2 represents an attempt to show the type of dynamic change that takes place in a typical boreal mixedwood forest over a 125-year period of forest succession.

Stage A: 25 years after wildfire

Pioneer aspen and/or white birch dominate the upper layer. They are taller than the few pioneer jack pine and two to four times taller than the pioneer black spruce and white spruce in the middle layer. As a result of almost complete crown closure only a few balsam fir seedlings have been able to establish themselves in the lower layer.

Stage B: 50 years after wildfire

The pioneer aspen and/or birch and scattered jack pine that still 'dominate' the upper layer are just beginning to decline in vigor. They now support less foliage than in the preceding period. The effect of this lessening dominance is to release the black spruce and white spruce in the middle layer; the canopy then begins to shift from the fast growing to the slower growing pioneers. In the lower layer balsam fir becomes more abundant and both hazel and mountain maple are established in increasing numbers. Because the spruces continue to dominate, lack of light and severe root competition cause suppression in the understory.

Stage C: 75 years after fire

Many of the pioneer aspen and/or birch in the upper layers are defective, dying or dead. The longer-lived pioneer jack pine, black spruce and white spruce which were once suppressed in the middle layer now dominate or co-dominate the canopy. With the decadence of aspen-birch in the upper layer, openings in the canopy that were not filled by spruces from the middle layer provide ideal conditions for the spread and growth of balsam fir and shrub hardwoods in the lower layer.

Stage D: 125 years after fire

Most of the pioneer aspen and/or birch (in the upper layer) have died and the few jack pine that entered it are now very old and are

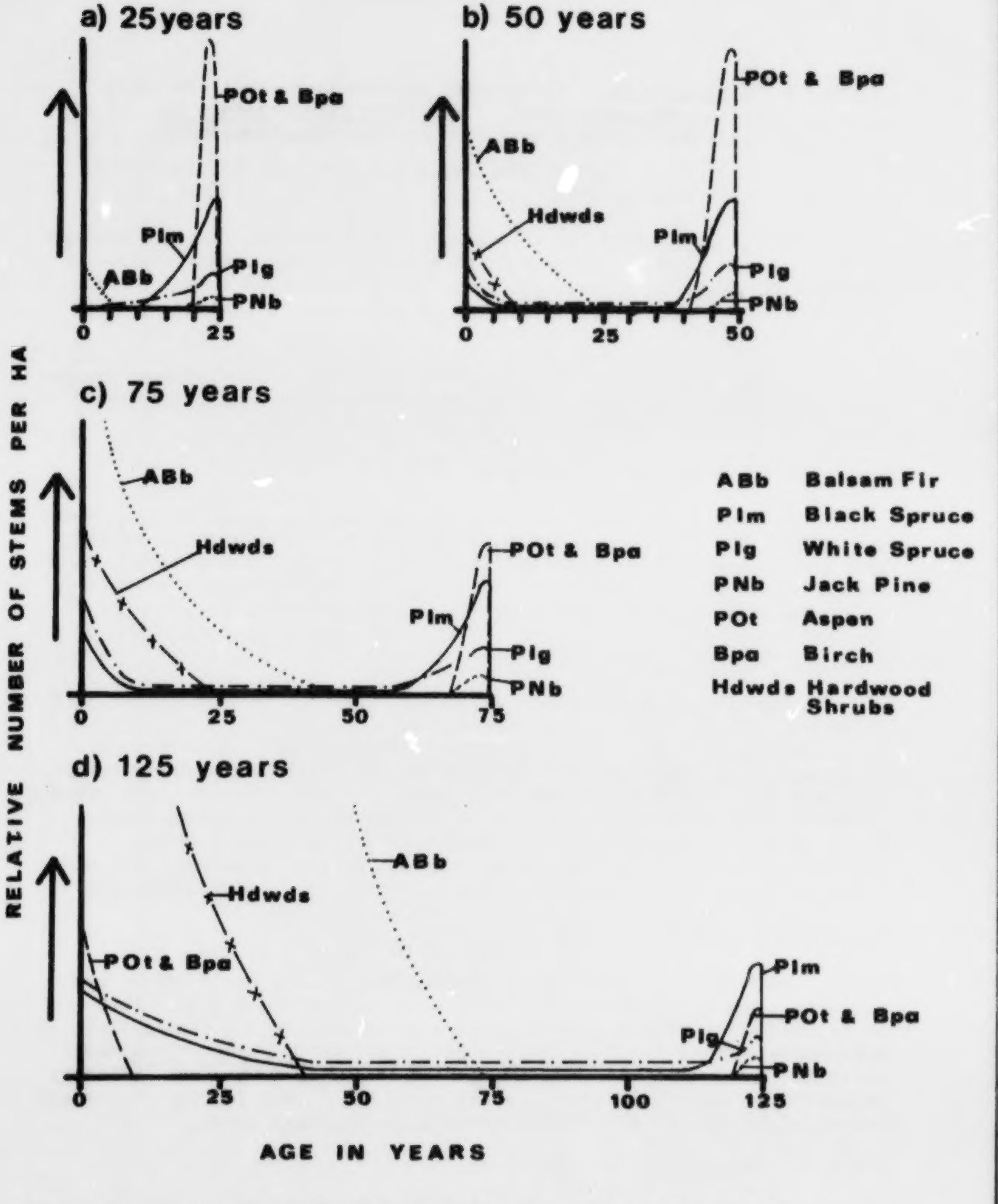

Figure 2. An hypothesis for the dynamic change taking place in boreal mixedwood forest with time elapsed from disturbance by wildfire.

losing foliage rapidly. The pioneer spruce from the middle layer now form the upper layer and dominate the stand. With further spread and growth, the balsam fir and hardwoods now occupy the middle and lower layers and form a self-perpetuating all-aged stand that prevents the reproduction of most other species. Because of the nature of the fire rotation (75 ± 50 years), it is unlikely that forest will be found in later successional stages.

CONCLUSION

The history of extensive forest fires in the boreal forest region has been traced back for centuries (Kelsall et al. 1977). Forest fires are a natural phenomenon in the boreal forest. It is likely that the vegetational diversity maintained by forest fires in the past was a prerequisite for the long-term stability of the boreal forest ecosystem (Zackrisson 1977). Plant species must adapt to the prevalent environmental conditions if the ecosystem is to survive. The suckering capacity of aspen, the serotinous cones of jack pine, and the semiserotinous cones of black spruce are obvious adaptations to a fire-dependent system.

Less evident is the fact that plant species are selected not only for fire survival mechanisms but also for an increase in their flammable properties, whereby they perpetuate the fire sensitivity of their environment (Kershaw 1977). The flammable bark of white birch and the resinous cones and bark of balsam fir tend to encourage wildfire in the boreal forest.

The exclusion of fire from the boreal mixedwood forests tends to minimize the pioneer phase and maximize the later successional phases. Old-growth stands are characterized by a few widely spaced and often tottering pioneer species emerging above an impenetrable tangle of balsam fir, mountain maple or beaked hazel. To anyone entering such a stand, the advantage of fire in eliminating deadfall and initiating a new stand of fast-growing pioneer species is very evident. A 'let-burn' program in parks would maintain the recreational, ecological and aesthetic value of these areas.

The current level of utilization of boreal mixedwood species creates serious difficulties in developing effective reproduction methods and silvicultural systems. Currently, most of the black spruce, white spruce and jack pine are cut for pulp and sawlogs but only the large-diameter aspen and birch are cut for veneer or flakeboard. After such partial felling, up to 25 m^3 of heavy slash and defective large-diameter and non-commercial aspen and birch remain, hindering both site preparation and planting. In addition, resuckering, resprouting and seeding of aspen and mountain maple guarantee that these species will dominate almost any seeded or planted coniferous crop. It is not the purpose of this paper to provide a silvicultural solution to the problem of current highgrading in the boreal mixedwood forest, but it is obvious that effective silviculture will depend on more complete utilization and a reduction of the regeneration potential of the hardwoods. To achieve these objectives new products and markets must be found, effective mechanical, chemical and prescribed burning methods developed for site preparation, and the use of herbicides introduced on a much larger scale to ensure that conifer crops are released and free to grow.

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ECOLOGICAL ROLE OF FIRE IN THE UNCUT BOREAL MIXEDWOOD FOREST

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Forest fires play a multiple role in the ecology of Ontario's boreal mixedwood forest: this forest is a fire-dependent ecosystem that would lose its character, vigor, and faunal and floral diversity in the absence of fire. The role of fire in land use planning and management, including the judicious use of random and planned ignition prescribed fires, must be considered more fully. Fire ecology research needs and opportunities are suggested.

Les incendies de forêt ont des effets multiples sur l'équilibre de la forêt boréale mélangée de l'Ontario: cette forêt constitue un écosystème qui dépend des incendies pour préserver son caractère, sa vigueur, la richesse de sa faune et de sa flore. En ce qui concerne l'aménagement des sols et la planification de leur utilisation, ce qui suppose notamment la mise à profit des incendies et la planification de brûlages dirigés, le rôle du feu doit être mieux examiné. Les possibilités qu'offrent ces pratiques et les besoins en recherche sur les relations entre les incendies et l'écologie sont présentés.

INTRODUCTION

The boreal mixedwood forests of northern Ontario are a complex quiltwork pattern or collage of pure stands and coniferous/deciduous mixtures of black spruce (*Picea mariana* [Mill.] B.S.P.), white spruce (*P. glauca* [Moench] Voss), balsam fir (*Abies balsamea* [L.] Mill.), trembling aspen (*Populus tremuloides* Michx.) and white birch (*Betula* *papyrifera* Marsh.) which were, and still are to a significant degree, related to the fire history of this area. Paleoecological analysis of charcoal deposits in lake and peat bog sediments in the Great Lakes region indicates that there have been periodic forest fires here for at least 9,000 years (Potzger 1950, Swain 1973, Raymond 1975). The regeneration mechanisms of black spruce, trembling aspen and white birch following fire are, in fact, adaptations that have evolved in a fire environment.

This paper reviews the principles of fire as an ecosystem process (Wright and Heinselman 1973, Heinselman 1978) and provides selected examples pertinent to the boreal mixedwood forests. It is essential for forest managers to understand and appreciate the fundamental roles of fire, as its occurrence in the boreal mixedwood forest is inevitable. They should be aware not only of the short- and long-term effects of fire, including the consequences of attempting to exclude it, but also of the ways in which they can use fire as a management tool.

There is a degree of variability in fire effects which is governed by the *fire regime* (i.e., intensity, recurrence interval, size, season of occurrence, depth of burn) and post-fire influences (e.g., climatic conditions) of a given area. For example, burn size is an important factor in wildlife habitat and seed sources, short-interval repeated fires may reduce site quality, and post-fire precipitation patterns determine conifer seedling survival.

INFLUENCE ON THE PHYSICAL-CHEMICAL ENVIRONMENT

Fire can be an effective decomposer and mineralizing agent. Some or most of the nutrients tied up in organic material are liberated and released as ash. Later they are deposited in the soil in sufficient quantity and in appropriate chemical forms so that surviving plants experience a net improvement in their environment (Ohmann and Grigal 1979). In the absence of fire, nutrient cycles and energy flow can be partially or severely blocked by incomplete decomposition of forest biomass (Heinselman 1978). The physical spalling and exfoliation of granitic and metamorphic rocks by fire may be the most important rock-weathering process contributing to soil formation on the Canadian Precambrian Shield (Wright and Heinselman 1973).

The physical removal, by fire, of certain vegetation components within a stand naturally alters microclimatic conditions. Increased insolation correspondingly results in higher soil temperatures which, in turn, stimulate pin cherry (*Prunus pensylvanica* L.) seeds to germinate (Marks 1974) and create the necessary environment to induce aspen roots to sprout (Horton and Hopkins 1966).

The impact of fire on environmental site quality is often of major concern. There is speculation that released nutrients such as phosphorus might cause eutrophication problems (i.e., algal blooms) in receiving lakes and streams. However, studies by McColl and Grigal (1977) and

Schindler et al. (1980) indicate that, except for an unusually short return interval and late season fires, there are no long-lasting, detrimental effects on water chemistry or biological properties. Post-fire vegetation ties up nutrients rapidly and reduces losses.

On the other hand, fire may expose varying amounts of mineral soil and, in so doing, increase the potential for surface erosion. Severe erosion is normally associated with steep terrain and immediate, heavy post-fire rains (Lutz 1956). Nevertheless, no measurable erosion was observed during two separate surveys of wildfire sites in northwestern Ontario (Armson et al. 1973, Methven et al. 1975). Fire-induced changes in the physical and chemical properties of the forest floor are greatly dependent on the degree of "duff" removal. Generally, a layer of organic material remains over a large portion of the area so that direct heating of the mineral soil is minimal.

CONTROLLER OF VEGETATION COMPOSITION, STRUCTURE AND SUCCESSION

Plant community composition is determined largely by the fire regime and the composition and nature of the pre-fire community. Other environmental factors are less important because of the relatively narrow range of climatic conditions and the broad range of plant tolerances (Grigal and Ohmann 1973, Ohmann and Grigal 1979). The autecological characteristics of the mixedwood tree species in relation to fire are well known[1] (Lutz 1956, Rowe and Scotter 1973, Ahlgren 1974, Viereck and Schandelmeier 1980). The mode of reproduction following fire is either by seed (conifers and hardwoods) or by vegetative means (hardwoods). MacLean (1960) states that "Fires create conditions that are usually favourable to reproducing white spruce, and unfavourable to balsam fir." Van Wagner (1979b) notes that "...black spruce...trembling aspen, and white birch--are ecologically equipped to spring back even after complete mortality over a wide area." The semiserotinous cones of fire-killed black spruce stems retain viable seeds for several years so that a live overhead seed source is not necessary (LeBarron 1939, Vincent 1965). White spruce and balsam fir, on the other hand, generally require "live seed trees" in the refugia of unburned areas within or adjacent to the burn (Rowe 1955, Bakuzis and Hansen 1965). Trembling aspen root suckering (Horton and Hopkins 1966) and the characteristic white birch whorls which originate from buds at the stem base are the usual means of recovery but both can reproduce by seed (Archibold 1980). Birch sprouting is more common in younger stands than in middle-aged and older stands (Lutz 1956).

Little duff removal by fire tends to favor the hardwoods since their regeneration mechanisms are not as dependent on the resulting seedbed conditions. Because of the preference of black spruce (and to some extent white spruce) for mineral soil, density and pattern following fire will vary in suceeding generations according to depth of burn.

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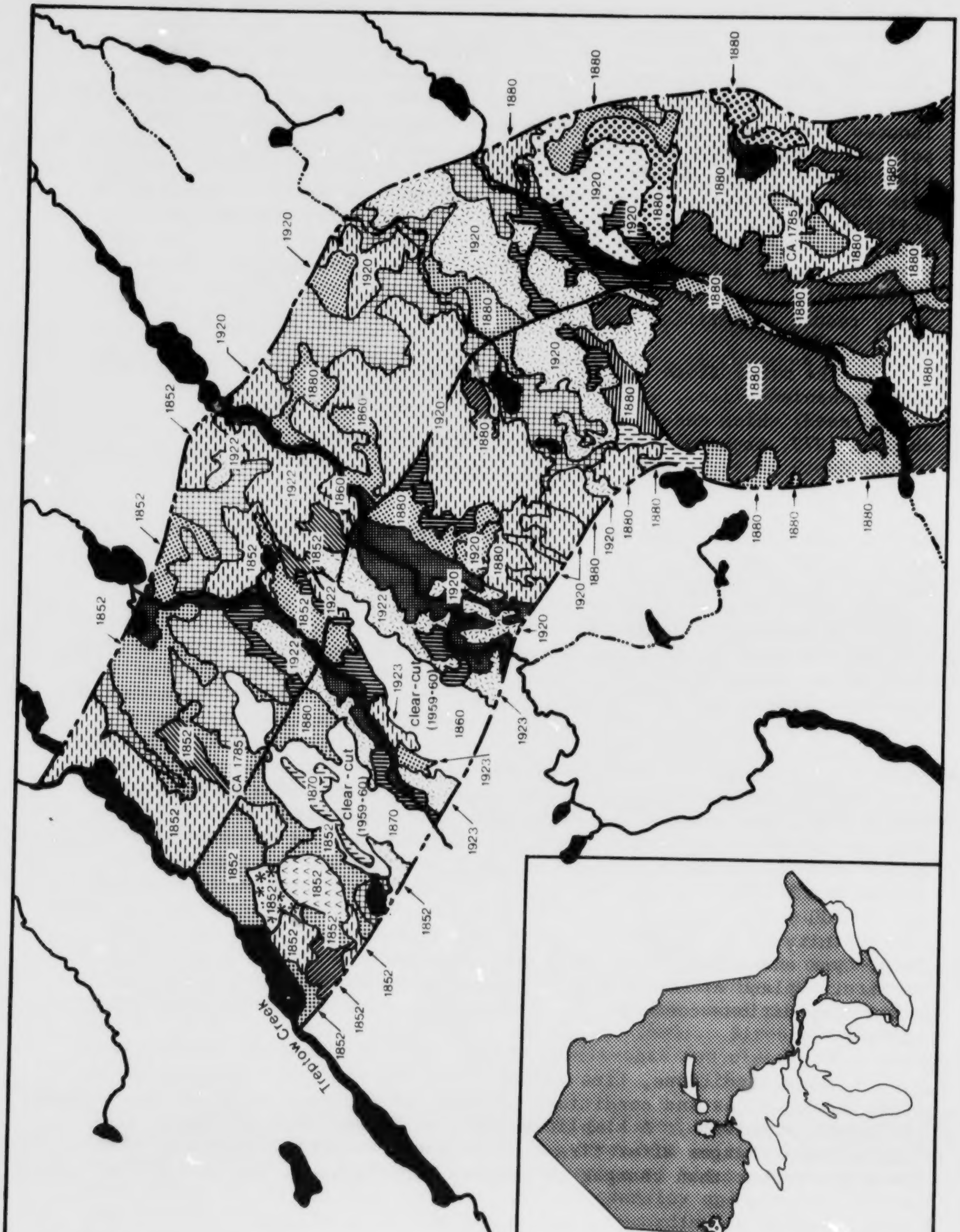
[1] See previous paper in these proceedings.

A short fire interval may promote aspen-birch or shrubs over spruce-fir because of the ability of the deciduous species to sprout/sucker at an earlier age than that at which conifers are able to produce abundant seed. A long fire interval may promote spruce over the hardwoods because of the greater longevity of conifers and the pathologically induced short rotations inherent in aspen and birch. Ahlgren (1974) points out that since fire frequently destroys the seed crop of young black spruce trees, natural selection may have favored genetic strains with the most vigorous height growth. Failures in conifer regeneration following fire are often attributed to unsatisfactory seedbed conditions, inadequate seed source or a combination of these factors. In such cases, trembling aspen and white birch may fulfill an important role in colonizing a site. For spruce seedling establishment, deeper burns temporarily reduce competition from lesser vegetation.

The minor flora indigenous to the mixedwood forest have regeneration mechanisms (i.e., wind dispersed seed, buried roots and rhizomes, stored seed) which ensure their survival (Marks 1974, Flinn and Wein 1977, Ahlgren 1979, Archibold 1979, 1980). Their response is dependent largely on the depth of burn, although fire frequency can also be a selective force (Methven 1978).

The patterns created by fire and physiography provide for a variety of stand ages, vegetation types and successional stages over the forest landscape (Fig. 1). The vegetation mosaic as a whole changes little over time; the fire-initiated patches "...like the pieces in a kaleidoscope--are periodically rearranged by fire and succession" (Heinselman 1978). The average number of years required to burn an area equivalent to the region as a whole is regarded as the *natural fire rotation* (Heinselman 1973) or *fire cycle* (Van Wagner 1978b). Van Wagner (ibid.) has shown that the stand age-class distribution in a natural fire-controlled forest should in theory fit a negative exponential function. The average stand age would be the same as the fire cycle; two-thirds of an area would have stands younger than the fire cycle and one-third would have stands that are older. Fire cycles prior to the initiation of fire protection have not been worked out for any boreal forest area in northern Ontario, although a study is in progress (Alexander 1978). Estimates of fire cycles for near-boreal conditions are 50-100 years (Heinselman 1973, Woods and Day 1977, Van Wagner 1978b). The scarcity of forest stands older than 150-200 years (e.g., MacLean 1960, Lynn and Zoltai 1965) is simply a reflection of the cyclic nature of fire. Upland areas burn more often than do lowland areas, simply because conditions conducive to fire spread occur more frequently on uplands.

Site conditions, fire variability, and the large variety of stand compositions and conditions provide for a number of possible courses of forest succession. A simplified case is illustrated in Figure 2. Vegetational changes after fire are changes in relative abundance and dominance rather than changes in species composition. The process is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CA 1785
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Treplow Creek

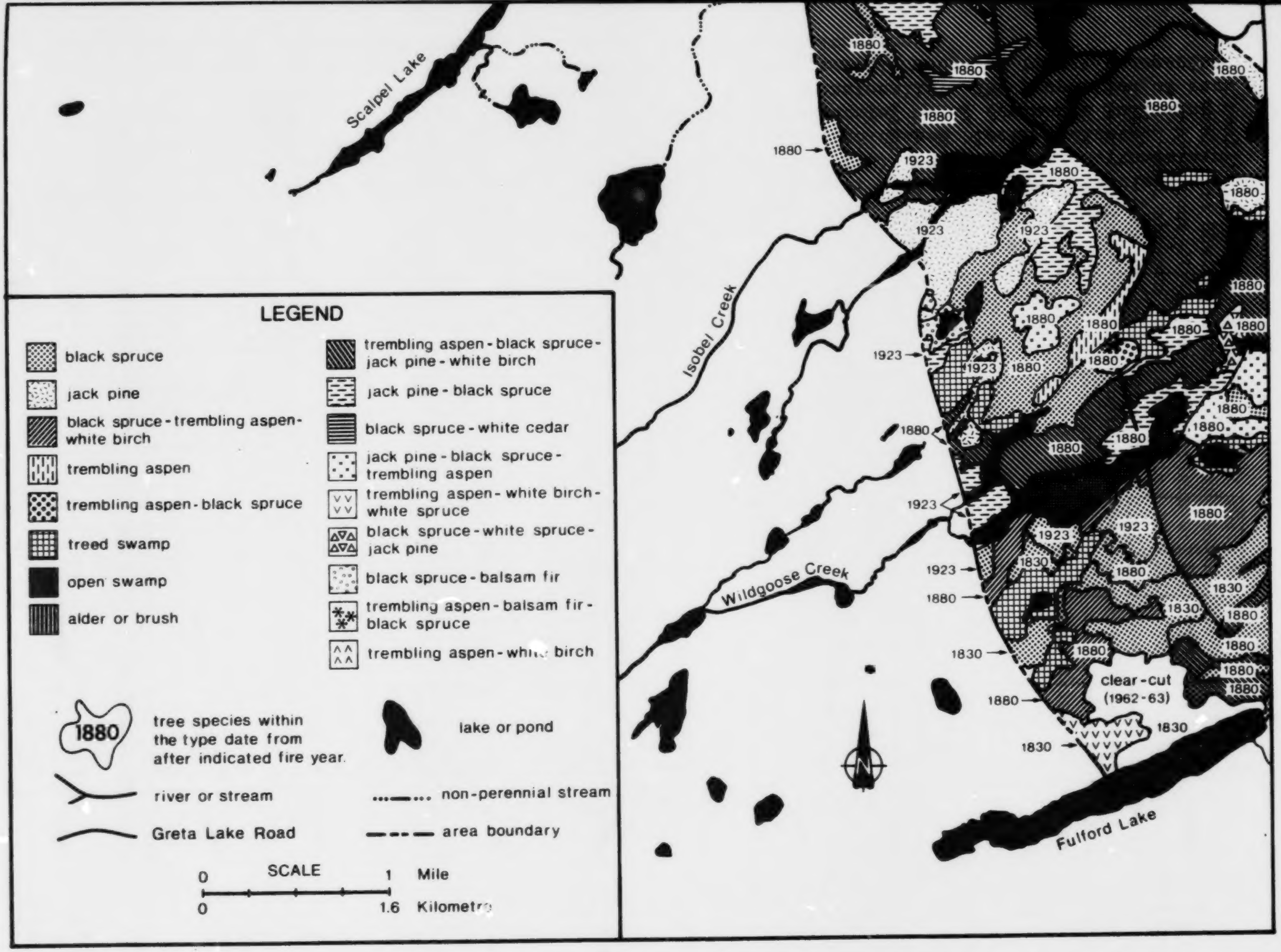
Scalpel Lake
Isobel Creek
Wildgoose Creek
Fulford Lake
clear-cut
(1962-63)
1830
1880
1923
LEGEND
black spruce
jack pine
black spruce - trembling aspen - white birch
trembling aspen
trembling aspen - black spruce
treed swamp
open swamp
alder or brush
trembling aspen - black spruce - jack pine - white birch
jack pine - black spruce
black spruce - white cedar
jack pine - black spruce - trembling aspen
trembling aspen - white birch - white spruce
black spruce - white spruce - jack pine
black spruce - balsam fir
trembling aspen - balsam fir - black spruce
trembling aspen - white birch
1880
tree species within the type date from after indicated fire year.
lake or pond
river or stream
non-perennial stream
Greta Lake Road
area boundary
SCALE
0
1
Mile
0
1.6
Kilometre

Figure 1. Composite stand fire origin and overstory vegetation map for a 54.4 km^2 area in the Geraldton Site District (5) - Lake Nipigon Site (3W) Region (49°56'N, 87°07'W) of north-central Ontario (adapted from Lynn and Zoltai 1965).

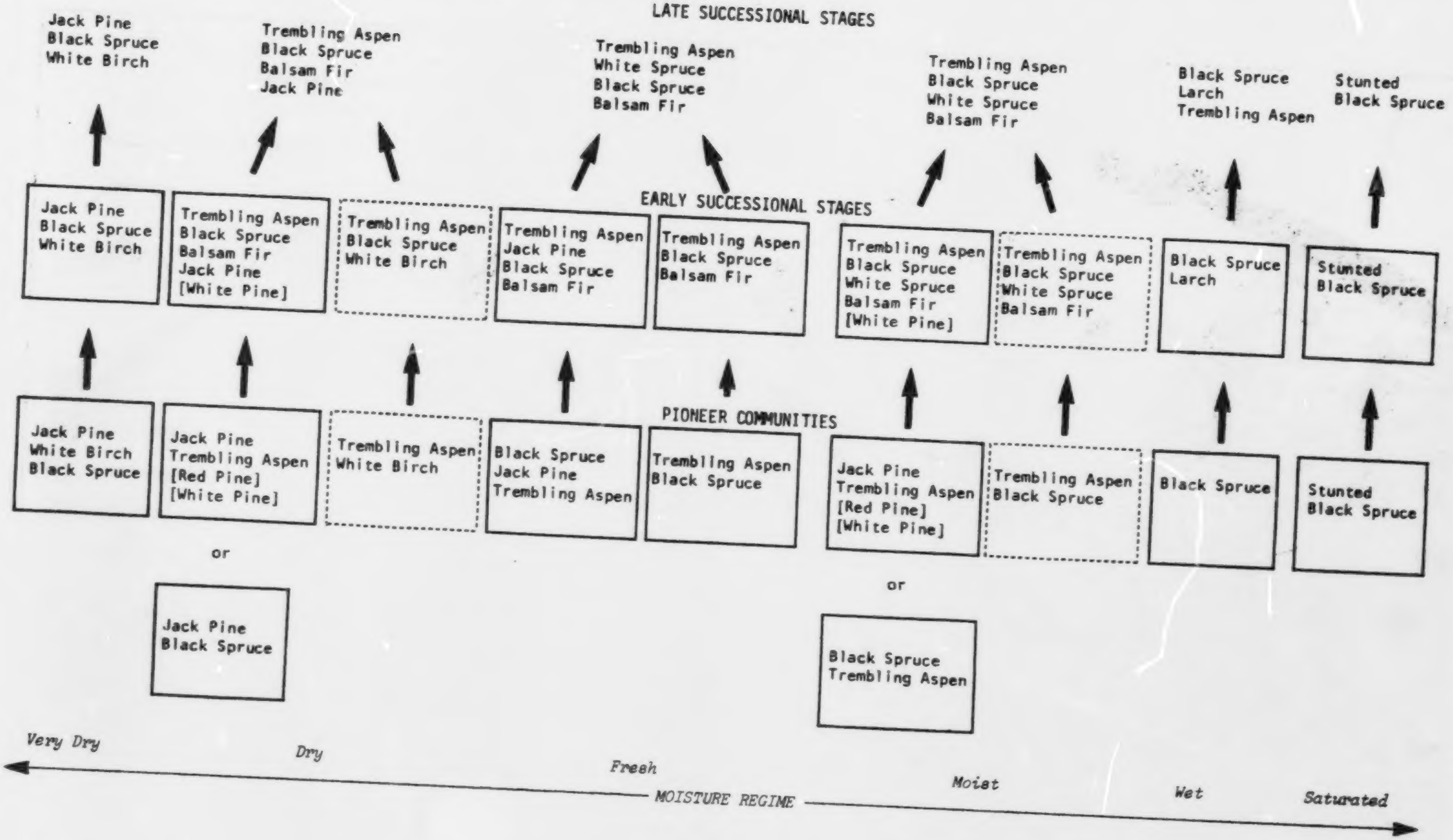
LATE SUCCESSIONAL STAGES
Jack Pine Black Spruce White Birch
Trembling Aspen Black Spruce Balsam Fir Jack Pine
Trembling Aspen White Spruce Black Spruce Balsam Fir
Trembling Aspen Black Spruce White Spruce Balsam Fir
Black Spruce Larch Trembling Aspen
Stunted Black Spruce
EARLY SUCCESSIONAL STAGES
Jack Pine Black Spruce White Birch
Trembling Aspen Black Spruce Balsam Fir Jack Pine [White Pine]
Trembling Aspen Black Spruce White Birch
Trembling Aspen Jack Pine Black Spruce Balsam Fir
Trembling Aspen Black Spruce Balsam Fir
Trembling Aspen Black Spruce White Spruce Balsam Fir [White Pine]
Trembling Aspen Black Spruce White Spruce Balsam Fir
Black Spruce Larch
Stunted Black Spruce
PIONEER COMMUNITIES
Jack Pine White Birch Black Spruce
Jack Pine Trembling Aspen [Red Pine] [White Pine]
or
Jack Pine Black Spruce
Trembling Aspen White Birch
Black Spruce Jack Pine Trembling Aspen
Trembling Aspen Black Spruce
Jack Pine Trembling Aspen [Red Pine] [White Pine]
or
Black Spruce Trembling Aspen
Trembling Aspen Black Spruce
Black Spruce
Stunted Black Spruce
Very Dry
Dry
Fresh
MOISTURE REGIME
Moist
Wet
Saturated

Figure 2. Observed and speculated successional trends in forest cover types by broad site classes associated with a normal ecoclimate in the Wabigoon Lake (4S) Site Region of northwestern Ontario (adapted from Zoltai 1965). Types within solid and dashed blocks indicate, respectively, conifer ("severe" burn) and hardwood ("moderate" burn) dominance following fire. Species within brackets are those which occur occasionally. The proportion of each species in each type can vary considerably. This diagrammatic model of forest succession averages the nutrient regimes in each of the moisture situations.

really one of forest development (Methven et al. 1975, Methven 1978, Janke and Lowther 1980). Contrary to Drexler's (1941) observations, many spruce-fir-aspen-birch stands are really of direct post-fire origin, for what appears to be succession is really just suppression (Heinselman 1973). Hughes (1967) dated a late successional stage mixedwood stand near Manitouwadge that contained remnant individuals dating from their fire origin in ca. 1761. Kendeigh (1947) describes a similar situation for a stand south of Black Sturgeon Lake originating after fire in ca. 1772.

Forests that experience little or no fire, termed "fire-independent" or "non-fire-dependent", are able to perpetuate themselves without periodic renewal by fire because other natural recycling mechanisms are involved. The role of fire as an agent that terminates and renews succession is ensured by setting up the proper conditions for the regeneration of a new stand. Recycling by insects and wind activity (e.g., Ghent 1958, Fye and Thomas 1963, Hughes 1967) in the boreal mixedwood forest seems far from complete because community succession is not set back as far as is the case with fire. What vegetation might develop in the absence of fire? Because of its shade tolerance, balsam fir is the only tree species apparently capable of continual establishment in the boreal mixedwood forest (MacLean 1960, Dix and Swan 1971, Grigal and Ohmann 1975, Carleton and Maycock 1978). Hence, extensive stands dominated by balsam fir in the tree stratum, and ultimately perpetuated by spruce budworm, would be the likely outcome.

DETERMINANT OF WILDLIFE HABITAT PATTERNS AND POPULATIONS

Although the popular image suggests that forest fires leave charred animal bodies littering the landscape, in reality there is very little evidence that fires kill substantial numbers of wildlife. Most animals are capable of avoiding fires by burrowing, running away, flying away, or escaping into water. Except for nests containing young or newborn mammals and birds which are not yet very mobile, wild animals are not particularly vulnerable to fires. In Alaska, for example, Hakala et al. (1971) reported that two large fires covering over 30,000 ha did not cause the animals in the area to panic. A family of swans (*Olor* spp.) and a moose (*Alces alces*) moved and fed in a small lake while the surrounding forest burned to the shore. A small group of woodland caribou (*Rangifer tarandus*) rested, were encircled by the fire, then moved away. Ruffed grouse (*Bonasa umbellus*) were heard drumming in unburned pockets of trembling aspen a week after the 6,000 ha Little Sioux Fire of May 1971 in northeastern Minnesota (Stenlund 1971). The fact that forest fires kill individuals cannot be disputed, but it is questionable whether fires depress whole populations (Cringan 1958, Buech et al. 1977).

The long-term habitat conditions created by recurrent fire are often excellent for wildlife. Some animals react to very specific conditions created by fire while others exploit the general pattern or mosaic of vegetation. For example, the sharp-tailed grouse (*Pedioecetes phasianellus*) of northern Ontario is particularly drawn to open and semi-open areas such as those that have been recently burned over (Hansen et al. 1973, Euler 1977). Birds that nest in tree holes or cavities take advantage of the snag patches produced by fire (Niemi 1978). At the other end of the spectrum are generalists like white-tailed deer (*Odocoileus virginianus*) and moose which use all successional stages and inhabit a wide variety of vegetation types. When the various habitat types are interspersed in close proximity, the value to these animals is enhanced. The fire mosaic, which is predominant throughout the boreal forest, benefits both specialists and generalists. Specialists benefit because through periodic fire the probability is enhanced that the particular set of conditions the species requires will exist. Generalists benefit because the mosaic contains a variety of conditions usually relatively well dispersed throughout the area.

In Ontario, moose are probably the most obvious example of animals exploiting recently burned areas (Cumming 1972). This relationship has been explored in numerous studies and the overwhelming evidence is that burned areas are beneficial to moose populations (Peterson 1953, Cringan 1958, Peek 1972, 1974, Hansen et al. 1973, Krefting 1974, Irwin 1975). As was noted in the editorial of the Winter 1978 issue of the *Ontario Fish and Wildlife Review* "...moose seem particularly drawn to openings created by fire. This may be a result of nutrient cycling caused by burning, but we don't really understand it." A fivefold increase in moose following the 1971 Little Sioux Fire was attributable initially to immigration of yearlings into the area but was subsequently sustained by increased productivity and survival.[1] Preferences for the fire-created mosaic have also been noted in a number of operational surveys in Ontario. A portion of the 1941 Gogama Fire area which, apparently, was excellent moose range was described by Vozeh and Cumming[2] with the aid of a forest resources inventory map. It consisted of 354 ha and supported 1.7 moose/km^2 in winter. Eighty-two percent of the area was composed of a stand that had reproduced following the burn 19 years earlier. It contained a mixture of tree species, 4-9 m tall, with a dense understory of shrubs and tree saplings. The remainder of the study area consisted of five rather long and narrow patches of mature conifers which constituted 18% of the total area. These stands contained patches of dense cover (8%) and were distributed around the edges of the study area. No part of the area was more than 0.5 km from a patch of mature coniferous cover.

The total moose population in Ontario is also a mosaic of population densities which expands and contracts as environmental conditions change. Moose populations have probably always fluctuated as fires disturbed various areas and as vegetation changed following those disturbances. Moose and fire have evolved together in the boreal forest and if fire were eliminated entirely, populations would certainly decrease drastically.

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[1] Peek, J.M., Professor, Coll. For., Wildl. and Range Sci., Univ. Idaho, Moscow. (personal communication, 29 September 1979).

[2] Vozeh, G.E. and Cumming, H.G. 1960. A moose population census and winter browse survey in Gogama District, Ontario. Ont. Min. Nat. Resour., Gogama District. 31 p. (unpublished report)

A dominant relationship between fire and wildlife in the boreal mixedwood forest is achieved through the particular conditions created when trembling aspen stands are favored by fire. Aspen is certainly the champion of several "phoenix" tree species in the boreal forest and would not exist in the same quantity without fire. The relationship between wildlife and aspen is clear; several wildlife species find aspen stands excellent habitat (Sharp 1971, Gullion and Svoboda 1972, Peek 1972, 1974).

Fire can influence predator-prey relationships since carnivores are dependent on herbivores and therefore on the fire-created vegetative mosaic. The story of the 1936 fire-moose-timber wolf (*Canis lupus*) association on Isle Royale is a classic example (Allen 1974, Krefting 1974). Fox's (1978) analysis suggests that forest fires are at least partially responsible for the cyclic nature of snowshoe hare (*Lepus americanus*) and associated Canada lynx (*Lynx canadensis*) populations.

Some animal species have been viewed as "climax species", adapted to and dependent on late successional stages of vegetation. Woodland caribou and pine marten (*Martes americana*), for example, are usually viewed as animals associated with the mature boreal forest. For them, the hypothesis suggests, fire is detrimental because it destroys their habitat (Devos 1948, 1952, Cringan 1957, 1958). More recent studies, however, illustrate that the relationship is more complex than was once thought. Woodland caribou have been shown to survive very well in early successional areas (Bergerud 1974, Euler et al. 1976, Davis and Franzmann 1979) and pine marten require some form of disturbance to produce the food items they need. Koehler and Hornocker (1977) concluded that fire was an important agent in establishing and maintaining a diversity of forest communities useful to marten.

CONTROLLER OF FOREST INSECTS AND DISEASE

Although there are a number of fire/disease and fire/insect interactions in the boreal mixedwood forest, the association of fire with spruce budworm (*Choristoneura fumiferana* [Clem.]) is paramount. When extensive stands of balsam fir-white spruce reach a susceptible stage, outbreaks of the budworm eventually lead to tree mortality and create fuel concentrations that make large-scale fires possible[3]. Such fires then eliminate the host trees and advanced balsam fir reproduction over sizable areas, thus terminating the outbreak and lessening the chance of future outbreaks. This may be a self-perpetuating mechanism ensuring that boreal mixedwood stands do eventually burn. Wood boring beetles which colonize fire-killed stems (Richmond and Lejeune 1945) provide an important food source for woodpeckers, nuthatches and other species which use the insect fauna of dead trees. We have observed that northern three-toed woodpeckers (*Picoides tridactylus*) thrive in recently burned areas.

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[3] Alexander, M.E. and Stocks, B.J. 1981. Fire and spruce budworm interactions in eastern North American spruce-fir forests. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. (in preparation)

The fact that black spruce dwarf mistletoe (*Arceuthobium pusillum* Peck) in Ontario is most commonly found in lowland areas is probably a reflection of higher fire intensities and "cleaner" burns on adjacent uplands (Alexander and Hawksworth 1976). The laboratory studies of Parmeter and Uhrenholdt (1976) suggest that forest fire smoke could inhibit germination of rusts and other fungi far beyond a fire's perimeter.

REGULATOR OF DRY-MATTER ACCUMULATION

Consumption of downed woody fuels, tree foliage, shrubs, etc., and reduction in organic mantle depth is an obvious and desirable feature of forest fires. Production of plant biomass generally exceeds decomposition as time elapses following fire in northern forests. The net result is that live and dead forest fuels gradually accumulate (e.g., "duff" depth increases with time since fire). The cyclic nature of fire causes a continual fluctuation between a very low and a persistent maximum biomass (Van Wagner and Methven 1981). An increase in potential fire intensity is not necessarily associated with fuel accumulation because fuel availability does not parallel an increase in forest biomass (Van Wagner 1979b). Flammability peaks early in stand development, falls as the stand matures and rises again as the stand begins to deteriorate.

CONTROLLER OF MAJOR ECOSYSTEM PROCESSES AND CHARACTERISTICS

Fire's role in regulating biotic productivity and maintenance of long-term ecosystem diversity and stability in northern forests has been the focus of much discussion in the ecological literature of late (e.g., Mutch 1970, Dix and Swan 1971, Heinselman 1973, 1978, Wright and Heinselman 1973, Bormann and Likens 1979, Van Wagner and Methven 1981). Productivity is almost always higher in early than in late stages of forest development (Hansen et al. 1973, Rowe and Scotter 1973). Fire can stimulate an increase in net primary production through changes in the physical-chemical environment (Ohmann and Grigal 1979). Dix and Swan (1971) felt that most areas in the boreal forest have "...undergone an infinite number of fire disturbances through time followed by an equivalent number of vegetational readjustments." The forest and its environment are linked in an irregular "pulse" strategy of alternating fire disturbance and regrowth that repeatedly rejuvenates the growing stock.

The fire-created vegetative mosaic provides for a variety of habitats--recent burns, newly regenerating stands, healthy maturity, decadence. This in turn determines plant and animal system diversity on a landscape scale. In the absence of fire we would expect ecosystem-wide progression to species-impoverished stands consisting principally of balsam fir. A significant end result of recurring fires is often expressed in terms of ecosystem stability (i.e., general long-term persistence). The stabilizing function of fire is effected through halting development and/or succession before instability becomes irreversible, i.e., before the community is radically altered (Van Wagner and Methven 1981).

MANAGEMENT IMPLICATIONS

Mutch (1970) advanced the hypothesis that *fire-dependent* plant communities had, through evolution, developed characteristics which made them more flammable. The extraordinarily high energy content (Hough 1969) and firebrand potential of white birch bark might be regarded as such an adaptation in the boreal mixedwood forest. However, we feel that the definition advocated by Kelsall et al. (1977) is more applicable to the boreal mixedwood forest--*it is a fire-dependent system that would lose its character, vigor, and faunal and floral diversity in the absence of fire.*

Certain forest/vegetation management practices can duplicate fire effects and even create habitat suitable for wildlife (Telfer 1974, Dolgaard et al. 1976, Euler 1977). The ecological rationale for broadcast burning of logging slash centres on the premise that natural conditions can be approximated (e.g., Tucker and Jarvis 1967, Robinson 1970, Perala 1974). Lower planting costs and fire hazard reduction are added benefits (Kiil 1971, Vyse and Muraro 1973).

Logging and slash burning may indeed be adequate substitutes for fire but what effect has fire protection had in the uncut portions of the boreal mixedwood forest? On the basis of percent mean annual area burned for 1920-1979, calculated fire cycles vary from 200 to 1,000 years (avg 500 years) in northern Ontario (Alexander 1980). There are, of course, no 500-year-old stands in northern Ontario but the present fire cycle is indicative of the increasing effectiveness of fire suppression. Logging has helped fill the gap between the burned area that would have occurred without fire protection and the area burned with fire protection. However, we may be seeing the consequences of fire exclusion already. For example, is the continuing spruce budworm outbreak being perpetuated by the existence--attributable to fire exclusion--of extensive areas of susceptible balsam fir? Are our parks becoming biologically quite different from the types of areas we planned to perpetuate?

On the other hand, one has to wonder about the economic wisdom of aggressive fire suppression. Forest fires are controlled more by weather than by fire control forces and suppression equipment. Some 75 years ago James Douglas[4] wrote:

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[4] Douglas, J. ca. 1905. The Conservation of Canada's Natural Resources (a lecture given at McGill College). Public Archives of Canada, M.G. 29, File B15, Vol. 54.

> "It is a question whether there could be much wisdom in spending large sums of money in a vain effort to preserve tracts of forest, only to meet their fate by fire. These conflagrations seem irresistible and the cost of preparing for a possibility of stopping them may exceed the value of the chance. Small forest fires may sometimes be influenced or partially controlled, but no way has been found to stop great conflagrations and I do not think they can be stopped."

In spite of a marked increase in suppression capability (and even with new technology) it seems that complete fire exclusion is impractical, if not physically and financially impossible, even for those areas under active management, in view of the fire environment (multiple fire starts, fuel complexes, fire climate, terrain) and inaccessibility of much of northern Ontario. Fire control forces can easily handle fires of low or moderate intensity but very likely the frequency of large-scale, high-intensity fires will increase with a continued policy of fire exclusion. Certainly logging companies cannot tolerate random fire in areas scheduled for cutting, but buying more hose or larger planes is not the answer. Obviously an ecologic-economic compromise is in order. Van Wagner (1978a, 1979a) and Martell (1978, 1980) have advocated a number of economic principles as a basis for considering fire in concert with land management in the boreal mixedwood forest. In addition, Euler (1975) has outlined a method by which the economic benefits of prescribed burning for creating favorable moose range can be judged.

Fire is a resource no less than the physical and biological components of the environment: without fire, the ecosystems that today characterize regions such as the boreal mixedwood forest would be something different. Fire should be considered from both an ecological and a protection point of view by those developing land and resource management objectives. Furthermore, once the objectives have been set, fire-related activities should be designed specifically to meet them, and not as an afterthought when all other planning has been completed.

The most commonly cited potential use of prescribed fires in the uncut boreal mixedwood forest has been associated with the renewal of overmature and decadent stands (e.g., Millar 1936, Larsson 1948). Other opportunities or possibilities for using "chance or random" (e.g., lightning) and/or "planned" ignition prescribed fires in standing timber include: wildlife habitat management (Gibson 1971, Steward[5]); hazard reduction and stand conversion in spruce budworm-killed areas (Alexander and Stocks[3]); park management (Woods and Day 1977, Alexander and Dubé 1979); and modified suppression programs on non-commercial timberlands (Harrison[6]).

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[5] Steward, R.W. 1975. A proposal for the evaluation of controlled burns as a moose management tool in the Cochrane District. Ont. Min. Nat. Resour., Cochrane District. 20 p. (unpublished report)

Fire prevention posters, messages, and literature have an important influence on public attitudes and therefore we should consider carefully the messages they communicate (Stankey 1976). Unless the public is kept informed of the natural role of fire and the beneficial uses of fire, it is liable to continue to insist on total fire suppression.

RESEARCH NEEDS AND OPPORTUNITIES

The science of predicting fire behavior and effects is in its infancy and the many ramifications of continued fire exclusion are not fully understood. Nevertheless, we cannot wait until we have all the facts and figures in hand. We must assemble and synthesize available information and prepare guidelines in support of fire/land management. Research conducted in other parts of the boreal forest (Alaska to Newfoundland) can provide an additional source of information. Managers may be forced to make qualitative predictions. Computer simulation may prove to be the most useful tool for analyzing the effects of current and forecasted levels of fire protection on forest resources (e.g., Van Wagner 1978b).

The following specific research needs are deemed worthy of future study. The applicability of the results and the likelihood of problem solution were the main factors in the selection process.

1. Quantification of fire characteristics vs. possibilities for post-fire development (e.g., depth of burn vs. seedbed and understory flora; fire intensity vs. available seed).

2. Relationship between organic mantle thickness and stand fire history, site type, etc.

3. Resulting vegetative mosaic, given potential fire behavior and physiographic features.

The importance of fire behavior relationships, from the standpoint of fire effects and fire growth predictions, cannot be overemphasized. Some progress is being made in this research area for other northern Ontario fuel complexes (Stocks and Alexander 1980).

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[6] Harrison, R.J. 1979. Fire Management Scheme for the Islands of Lake Nipigon and Black Bay Peninsula. Oral presentation at the Ontario Ministry of Natural Resources State of the Art Fire Management Seminar (Feb. 19-22, Geneva Park, Ont.).

What is the best approach to organizing a program that will address these specific needs? It would be overly optimistic to expect a single research unit to handle the entire program. A committee (perhaps under COJFRC sanction) is needed to serve as a catalyst, promoting research in specific areas, and as a coordinator. Representattives from OMNR, the CFS, universities and industry should be included in the membership. Field staff should begin their own monitoring programs.

Wildfire sites serve as ready-made study areas and present a number of possibilities for investigation. Ahlgren (1974) has, since 1950, established and monitored vegetational development on permanent plots in a number of areas in the Quetico-Superior region. Similar work was initiated in 1976 by the Great Lakes Forest Research Centre in northwestern Ontario (Stocks and Alexander 1980). An excellent example of initiative at the field level is the Chabbie Lake Burn Study Area (49°35'N, 79°46'W) in OMNR's Cochrane District which was established to monitor vegetation development and changes in moose utilization following a 325 ha wildfire in 1975.[7] The project has continued in spite of changes in personnel. Permanent plots established on recent wildfire sites have several advantages over survey efforts (e.g., fire behavior and pre-fire stand structure are more easily reconstructed since the "evidence" is still fresh).

Planned ignition prescribed fires afford many more opportunities for data collection. A prescribed fire on the southern half of Geikie Island (1100 ha) in Lake Nipigon was first proposed in 1977 by OMNR Nipigon District fish and wildlife staff.[8] A moose browse and pellet group survey was undertaken so that the effect of the burn in terms of browse creation and subsequent changes in moose utilization after the fire could be better evaluated.

The mapping of patterns resulting from wildfires (burned vs. unburned) would eventually result in a library of "case studies". This should be common practice for all moderate and large fires (say > 1,000 ha).

The possibility of relocating and redoing previous surveys (e.g., Hosie 1953) is worth investigating. Reconstructing old photographs and establishing permanent photo points may provide a valuable record of forest development following fire for use in public education programs.

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[7] Armstrong, E. 1980. Forest successional changes in the Chabbie Lake Burn Moose Browse Study Area, 1975-1979. Ont. Min. Nat. Resour., Cochrane District. 23 p. (unpublished report)

[8] Beange, D.B., Conserv. Off. Coord., Ont. Min. Nat. Resour., Nipigon District. (Personal communication 22 August 1977)

CONCLUDING REMARKS

Is fire a destructive menace or a natural process? Forest fires pose a difficult problem to land managers--should they try to exclude fire and face unwanted ecological change, or tolerate fire and risk resource damage and public condemnation? Fire in the boreal mixedwood forest is neither good nor bad except in terms of the degree to which it promotes or hinders land management objectives. The fact that we have acquired conditioned attitudes regarding fire complicates matters because managers, planners, policy analysts and the general public may be suggesting solutions to land management problems that disregard the long-term environmental significance of fire. Many managers view fire simply as a silvicultural tool (Sloane 1960). As developed earlier, the post-fire transformation of a site is essential for the survival and rejuvenation of the forest. The long-term effects of fire may sometimes offset the initial inconvenience and direct impact. What appears to be an aesthetic and economic disaster is really a normal and necessary process. Fire management programs will be effective only when the ecological role of fire is appreciated and integrated into land use planning and management.

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NATURAL SUCCESSION FOLLOWING HARVESTING IN THE BOREAL MIXEDWOOD FOREST

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Abundant trembling aspen and balsam fir were present on cutover boreal mixedwood areas 5 to 30 years after harvesting. Black spruce, white spruce, white birch and balsam poplar were also present. Original stand type, soil moisture, logging system, and degree and season of cut were also significant variables affecting fifth-year regeneration results. A preliminary set of predictive stocking equations is presented.

Le Peuplier faux-tremble et le Sapin baumier existaient en abondance dans les régions des forêts boréales mixtes récoltées depuis 5 à 30 ans. L'Épinette noire, l'Épinette blanche, le Bouleau à papier et le Peuplier baumier y apparaissaient aussi. Le type de peuplement initial, l'humidité du sol, le système d'exploitation ainsi que le niveau et la saison de la coupe constituaient aussi des variables importantes affectant les résultats observés la cinquième année quant à la régénération. Une série préliminaire d'équations de prédiction du matériel sur pied est présentée.

INTRODUCTION

Forest succession is the progressive development of a forest stand toward its highest ecological expression--the climax forest. It is a process of community development that is more or less orderly, directional, and, within certain limits, predictable (Odum 1969). Secondary succession resulting from logging operations is of particular importance to foresters since it is an integral aspect of forest renewal--an essential feature of sustained yield. A knowledge of secondary succession following disturbance of the original forest is essential to the successful management of any forested area.

Between 1954 and 1980, regeneration surveys were carried out on a variety of cutovers on the American Can Canada Inc. licence near Manitouwadge. In addition to basic regeneration data, physiographic and harvesting information was collected. The cutovers ranged in age from 5 to 30 years and most of the data from the older cutovers were from resurveys of stands originally surveyed 5 years after logging.

This paper presents the results of two investigations: an analysis of the extent to which various site and logging conditions influence regeneration following cutting, and an assessment of the successional trends of this regeneration during the first third of the rotation.

RESULTS

The tree species most commonly found on cutover areas were balsam fir (*Abies balsamea* [L.] Mill.) and trembling aspen (*Populus tremuloides* Michx.). Other species found were black spruce (*Picea mariana* [Mill.] B.S.P.), white spruce (*P. glauca* [Moench] Voss), white birch (*Betula papyrifera* Marsh.) and balsam poplar (*Populus balsamifera* L.). Jack pine (*Pinus banksiana* Lamb.) was rare.

A summary of regeneration results is presented by site and logging condition in Table 1. These factors and some interactions were analyzed by the least squares method to assess their impact on natural regeneration patterns (Table 2).

Cover Type

The presence or absence of various species in the original stand could be expected to have some impact on stand composition following logging. This expectation is borne out by the results presented in Table 1.

It is commonly accepted that most regeneration of the boreal hardwood species results from vegetative reproduction--either root suckers or stump sprouts--and would, therefore, require representation in the original stand. Tables 1 and 2 clearly illustrate this, with the hardwoods best represented on cutover hardwood (H) stands and least represented on cutover softwood (S) stands.

The conifer species which, in upland stands, usually regenerate from seed, the bulk of which is dispersed over short distances only (Fowells 1965), would require representation of seed-producing trees in or close to the original stand. Tables 1 and 2 indicate that conifer stocking is highest in softwood cutovers and lowest in hardwood cutovers.

Only spruce and aspen stockings are significantly related to cover type, probably for the reasons just mentioned. Although the figures in Table 1 would seem to indicate a similar association for balsam

Table 1. Percentage of quadrats stocked five years after logging near Manitouwadge, Ontario.

Factor	Category	No. of trees	Average percentage of quadrats stocked to						
			Spruce	Balsam fir	Aspen	White birch	Conifers	Hardwoods	All
Original cover type	softwood	65	25.99	33.19	18.83	10.08	49.71	30.05	66.00
	mixedwood	83	12.87	24.67	30.69	10.96	35.63	42.14	63.40
	hardwood	34	12.39	20.86	51.47	8.41	29.04	60.55	73.96
Site	dry	22	19.94	15.76	25.18	8.36	32.23	34.95	54.28
	fresh	85	16.10	26.41	42.17	10.82	38.82	51.83	73.27
	moist	50	14.98	29.62	24.65	10.36	38.85	36.95	62.55
	wet	25	24.90	33.68	6.01	9.81	48.96	19.51	60.68
Logging method	manual - horse skidding	39	18.33	19.06	28.97	5.64	33.66	39.71	61.93
	cable yarding - tree length	72	16.86	35.04	29.04	13.80	44.28	41.24	69.81
	cable yarding - bundle	32	21.19	22.68	26.55	9.09	41.61	35.84	62.93
	other[a]	39	14.67	23.64	37.19	8.80	34.44	47.29	66.95
Degree of cutting	clearcut	109	17.48	23.46	32.28	8.35	37.01	41.72	65.51
	heavy partial cut	73	17.43	32.29	27.43	12.89	43.04	40.57	67.47
Season of cut	spring	31	15.30	21.02	38.91	11.27	34.15	47.85	69.31
	summer	80	14.43	27.29	30.43	11.65	37.00	44.55	66.41
	dormant	71	21.82	29.98	26.48	8.02	44.47	34.67	64.87
Season of forwarding	snow-free	67	16.34	28.90	32.45	11.68	39.42	43.93	67.60
	snow	115	18.11	26.01	29.10	9.29	39.43	39.70	65.54

[a] Includes tree-length--tractor and arch yarding and 8-ft (approx. 2.4 m) bundles--bulldozed strip, crane loading and tractor haul.

Table 2. Analysis of variation of percentage stocking of spruce, balsam fir, aspen, white birch, conifers and hardwoods 5 years after logging near Manitouwadge, Ontario.

Source of variation	Degrees of freedom	Spruce		Balsam fir		Aspen		White birch		Conifers		Hardwoods	
		MS[a]	F[b]	MS	F	MS	F	MS	F	MS	F	MS	F
MAIN EFFECT													
Cover type (CT)	2	2959.80	11.13**	588.50	1.37	3775.30	7.53**	45.49	0.39	3501.90	7.73**	3732.30	7.71**
Site (SI)	3	313.09	1.18	1193.10	2.78**	4038.60	8.05**	69.20	0.59	695.20	1.54	3161.30	6.53**
Logging method (L)	3	319.20	1.20	2115.90	4.92**	980.30	1.95	446.50	3.79*	1046.20	2.31	746.14	1.54
Degree of cut (DC)	1	3.10	0.01	2681.30	6.23*	858.12	1.71	1006.50	8.54**	1145.10	2.53	18.68	0.04
Season of cut (SC)	2	545.36	2.05	1440.40	3.35*	879.57	1.79	100.91	0.86	1483.80	3.28*	1800.30	3.72*
Season of forwarding (SF)	1	31.37	0.12	196.83	0.46	102.88	0.21	0.99	0.21	152.28	0.34	87.86	0.18
INTERACTIONS													
CT x SI	5	68.74	0.26	376.82	0.86	157.09	0.31	315.70	2.68*	517.78	1.14	148.49	0.31
CT x DC	2	58.19	0.22	33.53	0.78	1281.00	2.55	7.98	0.07	134.67	0.30	874.36	1.81
CT x SC	4	280.77	1.06	360.38	0.84	20.73	0.04	142.20	1.21	521.92	1.15	106.65	0.22
SI x DC	3	181.95	0.68	580.23	1.35	1120.10	2.23	10.80	0.09	743.10	1.64	1917.70	3.96**
DC x SC	2	323.31	1.21	31.83	0.07	309.56	0.62	162.86	1.38	214.33	0.47	197.25	0.41
RESIDUAL	153	265.93		429.84		501.66		117.82		452.86		483.00	
TOTAL	181												

* Significant at the 5% level

** Significant at the 1% level

[a] Mean square

[b] Mean square divided by residual value

fir, statistical analysis indicates no relationship between balsam fir stocking and original cover type. Perhaps the figures are confounded by other factors such as the extent to which balsam fir was represented in the original stand, the age of the original stand, etc. In any event, it is obvious that balsam fir regenerates well regardless of original cover type, and this fact has significant management implications.

Stocking to white birch remains relatively constant throughout the three cover types examined. Since this species also regenerates reasonably well by seed where there is suitable ground disturbance, as well as from root suckers and stump sprouts, the fact that birch was usually left uncut (thereby providing a good seed source) may explain the relative uniformity between cover types.

Site

In this study the only parameter used to describe site was moisture regime. However, for the boreal mixedwood sites normally found in this part of Ontario, moisture regime provides a reasonable approximation of site productivity with the fresh and moist sites usually more productive than the dry or wet sites.

As is evident in Tables 1 and 2, only aspen and balsam fir regeneration were significantly correlated with site. For aspen this correlation is no doubt a reflection of the ability of the species to compete vigorously on the more productive sites and its inability to tolerate the more extreme conditions, particularly high soil moisture content. Balsam fir, while capable of establishing itself within the full range of moisture conditions, appears to regenerate better on wetter sites. This may be a reflection of the intense competition afforded fir and other conifer species by the many other species that proliferate on the best sites.

Logging Method

Different logging equipment and systems, depending on the degree to which they damage young growth and disturb the forest floor, and on the amount and distribution of the slash they leave, could be expected to have differing effects on subsequent regeneration patterns. Since various types of mechanical harvesting have been practised on the American Can licence since the late 1940s, the data were analyzed to determine if logging methods had any effect on regeneration.

The results indicated that only fir and birch regeneration were significantly influenced by logging method, and that regeneration was best on sites that had undergone tree-length yarding. Since horse skidding and bundle yarding normally cause less damage to advance growth than does tree-length yarding, this improvement must have been in regeneration other than advance growth. Perhaps tree-length yarding provided a better distribution of soil disturbance and slash, so that seedling ingrowth more than compensated for mortality caused by logging equipment.

Degree of Cut

In past logging operations in boreal mixedwood stands there was a great deal of partial cutting. In most operations only the conifer component was removed, but in some a portion of the hardwood species may also have been harvested, usually for veneer logs. Since the residual trees often hamper or even prevent silvicultural treatments, natural regeneration may be all that can be expected.

The results of this study indicate that balsam fir regeneration is much better on partially cut stands and that the reverse seems to be true for aspen (although the difference is not significant at the 5% level). These results should not be surprising in view of the difference in shade tolerance and the importance of increased soil temperature as a stimulus to aspen root suckering.

Cutting Season

The results presented in Tables 1 and 2 indicate that the season of cutting had no effect on aspen regeneration levels five years after cutting. This finding appears to contradict a current theory that aspen regeneration could be inhibited by cutting at a time when root reserves are at a low level.

For fir and the conifer species as a group, the later in the season that cutting takes place, the better the regeneration. Perhaps this is because seed matures and is dispersed in late summer or early autumn.

Season of Forwarding

Because of the movement of skidding equipment and trees from stump to roadside there is a potential for damage to existing young growth, for site damage due to compacting, rutting or erosion, for increased seedbed exposure, and for improved slash breakdown and distribution. This potential can perhaps be changed significantly by snow and frost conditions at the time of forwarding. However, such a hypothesis has not been substantiated by the results of this study, in which, under the conditions surveyed, the season of forwarding appeared to have little impact on natural regeneration results.

It should be pointed out, however, that all but 39 of the stands sampled were forwarded either by horse or by some form of cable yarding. Since both systems are recognized (Frisque et al. 1978) as causing relatively little damage to advance growth, the results might be different if more modern methods of forwarding were better represented in the surveys.

Interactions

Although regeneration levels and patterns could conceivably be affected by various interactions among the main factors, an analysis of several possible interactions indicated that, in general, there were no significant differences.

SUCCESSIONAL TRENDS

Just as important as the amount, type and distribution of natural regeneration following logging are the developmental trends of that regeneration with the passage of time. With the data collected as part of this study it was possible to observe successional trends over the first 30 years of the next rotation.

Table 3 indicates a general increase in stocking distribution from the fifth to the tenth year for all species. However, the rate of recolonization was much slower in the second 5-year period than in the first, probably as a result of a reduction in suitable seedbed area and a concurrent increase in competition afforded any newly germinated seedlings by established vegetation. Although the stocking trend was, in general, positive (i.e., stocking increased), individual stands often exhibited substantial changes in stocking levels, both positive and negative, reflecting the dynamic nature of the colonizing and consolidating process during the first 10 years.

Tables 4 and 5 present the relative frequencies by size class of the various species components in cutover mixedwood and hardwood stands, respectively, 15 to 30 years following harvesting. It is evident from these tables that the mixedwood cutovers, up to 30 years, remained in the mixedwood category whereas the hardwood cutovers, up to 25 years, seemed to have been converted to mixedwood. It is also evident that most of the conifer in the new stands, both on a numerical and on a basal area basis, was balsam fir.

By the time the hardwood and mixedwood cutovers reached 15 years of age, there was virtually no ingrowth of aspen. Its density had decreased steadily but any basal area losses due to mortality were more than compensated for by a steady upward growth from one size class to another. In terms of basal area, aspen was the major species in both cover types.

Spruce densities appeared to peak at about 15 years in both cover types and then began to decline slowly. However, mortality continued to be offset by diameter growth to such an extent that species basal area in the mixedwood stands increased in relative proportion to total basal area and, in the hardwood stands, remained relatively constant. At this point spruce appears to be at least maintaining its position in the new stands, albeit as a minor understory species.

Table 3. Changes in percentage of quadrats stocked in the boreal mixedwood forest near Manitouwadge, Ontario, 5 and 10 years after harvesting.

Cover type	No. of stand	Years since cut	Spruce	S.E.[a]	Balsam fir	S.E.	Jack pine	S.E.	Aspen	S.E.	Balsam poplar	S.E.	White birch	S.E.	Coni-fers	S.E.	Hard-woods	S.E.	All	S.E.
Softwood	24	5	19.19	2.75	33.86	4.23	-	-	14.25	2.46	2.89	1.26	8.65	2.66	43.31	3.18	23.56	3.58	61.30	3.07
		10	22.46	2.57	39.50	3.60	0.29	0.20	18.71	2.59	2.96	0.82	14.39	2.96	51.22	3.05	31.52	2.68	67.09	3.10
Net changes			3.27		5.64		0.29		4.46		0.07		5.74		7.91		7.96		5.79	
Mixedwood	105	5	13.50	1.32	26.15	2.12	1.97	0.49	39.50	1.98	5.08	0.66	8.39	0.96	37.23	2.11	47.66	1.90	69.51	1.66
		10	18.21	1.53	28.26	2.11	3.04	0.54	42.00	2.43	6.49	1.00	13.89	1.47	42.25	2.11	54.46	2.14	74.53	1.71
Net changes			4.71		2.11		1.07		2.50		1.42		5.50		5.02		6.80		5.02	
Hardwood	20	5	5.99	1.75	10.79	2.57	0.46	0.31	55.95	6.11	4.44	1.63	3.26	1.28	16.42	2.40	60.03	5.95	66.70	5.35
		10	8.51	1.61	12.84	3.91	1.98	1.24	59.32	3.92	11.55	2.90	8.45	2.48	22.48	9.14	66.84	3.49	75.68	3.07
Net changes			2.52		2.05		1.52		3.37		7.11		5.19		5.06		6.81		8.88	

[a] Standard error

Table 4. Composition and size distribution of tree species in the boreal mixedwood forest near Manitouwadge, Ontario following harvesting.

Years since cut	Size class[a]	Black spruce	White spruce	Balsam fir	Jack pine	Aspen	Balsam poplar	White birch	Total
					(stems per ha)				
	A	119	24	2,642	-	35	7	31	2,858
	B	370	84	1,431	-	73	28	38	2,024
	C	555	164	1,071	14	140	35	405	2,384
15	Subtotal	1,044	272	5,144	14	248	70	474	7,266
	<0.5 in.[b]								
	1 "	220	59	674	42	935	45	1,106	3,081
	2 "	45	14	352	28	695	24	192	1,350
	3 "	28	3	154	10	272	-	31	498
	4 "	17	3	108	-	66	3	-	197
	5 "	7	-	63	-	14	-	-	84
	6 "	-	-	63	-	-	3	17	83
	Subtotal	317	79	1,414	80	1,982	75	1,346	5,293
	TOTAL	1,361	351	6,558	94	2,230	145	1,820	12,559
	A	65	12	3,824		10	2	10	3,923
	B	51	8	1,052	-	13	20	33	1,177
	C	184	31	774	1	24	81	70	1,165
25	Subtotal	300	51	5,650	1	47	103	113	6,265
	<0.5 in.								
	1 "	115	17	418	12	315	50	386	1,313
	2 "	76	12	297	12	624	45	255	1,321
	3 "	53	8	209	9	508	25	119	931
	4 "	27	10	127	10	272	12	38	496
	5 "	18	2	87	7	119	8	11	252
	6 "	6	7	72	10	29	4	42	170
	Subtotal	295	56	1,210	60	1,867	144	851	4,483
	TOTAL	595	107	6,860	61	1,914	247	964	10,748
	A	34	28	4,939	-	3	-	3	5,007
	B	63	3	845	-	9	-	3	923
	C	139	14	447	3	3	9	14	629
30	Subtotal	236	45	6,231	3	15	9	20	6,559
	<0.5 in.								
	1 "	154	17	507	3	128	26	165	1,000
	2 "	117	11	407	3	455	43	134	1,170
	3 "	74	6	339	17	512	54	68	1,070
	4 "	65	17	205	3	253	34	34	611
	5 "	43	3	77	9	148	37	9	326
	6 "	20	11	94	3	97	17	28	270
	Subtotal	473	65	1,629	38	1,593	211	438	4,447
	TOTAL	709	110	7,860	41	1,608	220	458	11,006

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[a] Size class: seedlings: A--0 to 6 in. high; B--6 to 18 in. high; C--over 18 in. high but less than 0.5 in. DBH.

saplings: 1--DBH 0.5 to 1.4 in.; 2--1.5 to 2.4 in.; 3--2.5 to 3.4 in.; 4--3.5 to 4.4 in.; 5--4.5 to 5.5 in.; 6--5.5 in. and over.

[b] 1 in. = 2.54 cm

Table 5. Composition and size distribution of tree species in the boreal hardwood forest near Manitouwadge, Ontario following harvesting.

Years since cut	Size class[a]	Black spruce	White spruce	Balsam fir	Jack pine	Aspen	Balsam poplar	White birch	Total
					(stems per ha)				
	A	75	62	1,317	-	-	-	-	1,454
	B	81	169	1,239	-	-	-	10	1,499
	C	218	286	868	16	286	55	257	1,986
	Subtotal	374	517	3,424	16	286	55	267	4,939
	<0.5 in.[b]								
15	1 "	120	42	426	29	1,817	85	429	2,948
	2 "	23	3	328	-	1,282	20	88	1,744
	3 "	16	-	172	-	455	20	3	666
	4 "	10	7	78	-	62	3	-	160
	5 "	7	-	36	-	7	-	3	53
	6 "	13	-	45	-	-	3	49	110
	Subtotal	189	52	1,085	29	3,623	131	572	5,681
	TOTAL	563	569	4,509	45	3,909	186	839	10,620
	A	41	-	3,365	-	16	8	57	3,487
	B	16	-	1,097	-	24	24	-	1,161
	C	154	33	747	-	16	73	41	1,064
	Subtotal	211	33	5,209	0	56	105	98	5,712
	<0.5 in.								
25	1 "	195	16	390	-	333	171	228	1,333
	2 "	73	16	333	8	1,089	114	171	1,804
	3 "	41	24	130	-	796	57	73	1,121
	4 "	8	16	130	24	203	24	24	429
	5 "	-	16	65	24	187	-	8	300
	6 "	-	8	105	8	41	-	41	203
	Subtotal	317	96	1,153	64	2,649	366	545	5,190
	TOTAL	528	129	6,362	64	3,705	471	643	10,902

[a] Size class: seedlings: A--0 to 6 in. high; B--6 to 18 in. high; C--over 18 in. high but less than 0.5 in. DBH.

saplings: 1--DBH 0.5 to 1.4 in.; 2--1.5 to 2.4 in.; 3--2.5 to 3.4 in.; 4--3.5 to 4.4 in.; 5--4.5 to 5.5 in.; 6--5.5 in. and over.

[b] 1 in. = 2.54 cm

In the new stands, the numerical relationship of black and white spruce to each other is relatively similar to that in fire-origin, mature mixedwood stands.

In terms of density, balsam fir was, by far, the most numerous species present, and it increased in density between each age level for both cover types. Most of the fir stems occurred in the seedling size classes, providing a sufficient reservoir for a steady recruitment of numbers into the sapling classes at each age level. As fir is a shade tolerant species, the tremendous numbers of stems present on the forest floor may well remain for some time to come. In the sapling classes, while other species were decreasing in numbers, balsam fir was maintaining its numbers and steadily increasing in basal area. On the basis of diameter distribution relative to other species, it appeared to be occupying an intermediate or codominant position at all age levels in the new stand.

Insufficient data were available for preparation of a similar table for the softwood cover type.

With data obtained from the most recent surveys, it was possible to develop a set of regression equations that could be used to predict stocking levels in the mixedwood cover type. They are as follows:

$$\text{Conifer stocking \%} = 21.8966 + 0.03706 \times \text{years}^2$$

$$\text{Hardwood stocking \%} = 31.8358 + 2.26711 \times \text{years} - 0.05638 \times \text{years}^2$$

$$\text{Total stocking \%} = 47.1607 + 1.69005 \times \text{years} - 0.02388 \times \text{years}^2$$

NOTE: "years" = years since harvesting

These equations indicate steady increases in stocking over time for conifer species and for total stocking, and a peaking of hardwood stocking at about 20 years, followed by a slow decline. It should be pointed out that these are preliminary equations, and will require some revision after the 1980 data collection.

DISCUSSION

Although the study reported in this paper is not yet complete, a number of preliminary observations can be made on the basis of the range of conditions analyzed:

1) The boreal mixedwood forest exhibits, at least in terms of regeneration, a considerable resiliency in its recovery from logging disturbance. If the forester is prepared to accept any of the currently merchantable tree species in the next crop, then regeneration levels which meet current minimum stocking standards can be achieved readily without subsequent silvicultural treatment.

2) There does not appear to be much potential in varying the logging system to influence regeneration patterns. Balsam fir regeneration may be influenced to a degree by the selection of the logging system and the degree and season of cutting. Certainly, aspen regeneration levels are not affected by season of cutting nor does partial cutting in boreal mixedwood stands result in low regeneration levels.

3) The new mixedwood forest will be considerably different from its predecessor. Its area will probably increase as what were originally softwood or pure hardwood stands regenerate to a greater variety of species. The spruce component will probably occupy a much less important position in the future and balsam fir will be, by far, the major conifer species. Aspen volumes may not change greatly from those of the original forest.

4) The tremendous influx of balsam fir seedlings at least during the first third of the rotation implies even greater representation of this species in future rotations in the absence of silvicultural treatment favoring other species. It also begs an answer to the question of the impact of other major disturbances (e.g., the spruce budworm) that might reduce or eliminate the conifer overstory of these stands.

It would appear that trembling aspen and balsam fir will form the next crop on untreated boreal mixedwood cutovers. Therefore, because of the large area of untreated cutover mixedwood stands on which the next crop is now established, management practices that will ensure acceptable yields at the end of the rotation period will be needed.

The results imply that at least two management strategies are possible on boreal mixedwood sites: one which emphasizes early control of balsam fir and aspen numbers along with the establishment of spruce at a high initial cost for site preparation, regeneration and brush control; and another which accepts natural regeneration at a low initial cost with subsequent high protection costs to control the spruce budworm and bring the conifer component to maturity.

In view of the prolific regeneration of balsam fir in cutover mixedwood stands, it seems unlikely that we will ever be able to control fir numbers effectively on anything more than a small scale. In spite of efforts to the contrary, forests susceptible to spruce budworm will probably be with us for a long while.

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Discussion

M. Roberge: Professor Day, you said in your summary, "Let's burn balsam fir". Don't you think that's too drastic a measure?

R.J. Day: I would recommend a "let burn" policy in parks, particularly those parks classified as wilderness parks. Perhaps I should have included the word "wilderness" in the summary, as I certainly wouldn't recommend a "let burn" policy in some of the larger city parks in Ontario. I consider the use of fire in the parks to be a silvicultural measure.

G. Brown: This isn't a question but a comment on species growth. Once I had occasion, along with other foresters, to compare the the growth of conifer species in the boreal forest by measuring the first 20 years of growth. The range was from 25 cm for jack pine, which was the best performer, to 12.5 cm for black spruce, which was the poorest performer. Balsam fir was second and poplar third.

R.J. Day: I concur with George Brown; we do not know enough about the performance of species under management. Every time I have students do stem analysis on balsam fir on an old cutover they always come back and say, "Look at that". It's probably one of the more productive species, although in this case it wasn't. You had it further down the list than number one; jack pine was number one. One of the things I wanted to do when I came to Ontario was to set up experimental trials and attempt to grow various species over a range of spacings and environmental conditions. We will never know what performance to expect under management unless we do, in fact, manage. If we could establish at this meeting some reasonable silvicultural methodology for growing a variety of boreal species and compare them as crops, then we'd come closer to understanding the productivity of the species in the boreal mixedwood. As it is, we have a stratified mixture--one species suppresses the other. We also have a number of difficult environmental conditions which mask the real growth potential of the species. Balsam fir doesn't have to enter the stand as a late successional species. It can come in as a primary species right after wildfire, and it will give spruce and pine a run for their money on the better sites.

G. Pierpoint: The idea that removing fire from the ecosystem influences forest development and productivity in the future is extremely significant. Logging, too, has an effect. By the way, I was very interested in the vigor scale that you gave us for the species--the pioneering species particularly--with aspen and white birch, jack pine and black spruce being the most vigorous. Dick Fry and Richard Yang note in their paper that after logging there is an increase in aspen and fir, and aspen is on the more vigorous side of your scale. Economics plays a very significant role in management, but we must consider the ecological aspects of management as well. Because of the vigor and pattern after logging, should we be putting a lot more thought and effort into managing for aspen in the boreal mixedwoods after our cutting interference?

R.D. Fry: As a forester who has been exposed for quite a long time to aspen utilization in fairly large quantities, I believe that we should be managing aspen in pure stands and in mixedwood stands, as part of a crop that comes in naturally. I am dismayed when I see aspen treated as a weed species--something to be eliminated. A couple of times during this session and an earlier session it was stated that aspen seems to be increasing in the mixedwood stands or cutover mixedwood stands but our figures don't indicate that. They indicate that, at best, aspen is holding its own. In the next stand aspen will probably be found in the same volume or the same proportion as it occurred in the last crop. In hardwood stands it may occupy a slightly lesser position but still a dominant one. The species that is obviously going to increase is balsam fir and it's one that we must contend with.

SESSION III: FIBRE UTILIZATION IN THE BOREAL MIXEDWOOD FOREST

Wood-using complex of Great Lakes Paper Ltd., Thunder Bay, Ontario (Lucas Photographics, Thunder Bay).

SESSION III: FIBRE UTILIZATION IN THE BOREAL MIXEDWOOD FOREST

Introduction (*R.B. Loughlan*)

All my life I have been conned. My mother conned me into believing that spinach was good for me; my teachers conned me into believing that all girls were saints and virgins; my recruiting officer conned me into thinking I would have a wonderful time in the service; my forestry professors conned me into thinking that the profession was well advanced and that somewhere, somebody knew a great deal about it.

Later, when I began working for a living, plenty of other people tried to con me. I have had tractor and boat operators look me right in the eye and tell me they should be paid twice as much as the average fellow because they produce twice as much.

Most recently, foresters in the government and the academic community have tried to con me, and others in industry, into being the scapegoat for all that is wrong with forestry. Some say that the forest industry should be ashamed of itself for all the waste it leaves on cut-over areas. (This comment often comes from people in a certain Ministry who insist that along roads and waterways, substantial reserves be left where you can see millions of unused cunits blowing down.) Others say that the current clearcut practices are harmful to moose habitat. (And yet, biologists in the same Ministry to which I alluded above agree that clearcutting is beneficial to moose habitat.) Still others say that we should tailor the customer to fit the forest. (But the customer doesn't want poplar, doesn't need poplar, and won't pay for poplar.)

There are con artists at work, it seems to me, when companies are encouraged to expand, do so to the tune of millions of dollars, and then are threatened with the conversion to wilderness preserves of 60% of the area on which the expansion was based.

There are people who view with alarm the fact that we are approaching the allowable cut without acknowledging that the productive forest available for logging has been arbitrarily reduced by 42% in recent years, and there are thousands of square kilometres set aside as wilderness preserves which will contribute nothing to the economy.

It is getting so that all you can believe in these days are death, taxes, and the entrenchment of the Conservative government in Ontario.

So - there you are, gentlemen. If you are researchers and problem solvers, let's see your activities directed toward solving some of the industry's major problems. Don't tell me that we'll have to settle for balsam fir in the next rotation and in the same breath say that we can't afford to control the budworm which eats balsam fir.

Don't tell me that fires are good for you, like spinach.

Go back to the drawing board and give us good black spruce fibre to bring in export dollars and keep this economy spinning.

You didn't bring me here today to ruffle feathers or throw out challenges. You brought me in to be a chairman, and as of now, that's what I'll be.

First, F.L. Raymond, an OMNR researcher, will present a paper on exploring multiple linear regresssion as a tool for understanding and demonstrating the importance of some geographic and physiographic variables in estimating spruce volumes.

Then, M.A. Opper, an industrial forester, will show you, from the point of view of industry, why the present levels of utilization are what they are, what their effects are on silvicultural treatment, and what can reasonably be done to improve the situation.

Then, J.F. Flowers, an OMNR forester in the boreal region, will voice his concern about present and possible future management problems, from the point of view of the government agency responsible for forest management.

A paper has been prepared by M.R. Clarke, A.J. Dolenko and J. Carette of Forintek Canada Corporation on the opportunities that will be opening up in world markets as a worldwide timber supply crisis moves in on us. In this paper, programs at Forintek designed to enable the Canadian forest industry to use species which are at present underutilized will be discussed.

With these four papers, the problems and possibilities of fibre utilization in the boreal mixedwood forest will have been explored for you by experts.

I hope you will find them interesting.

SOME FACTORS AFFECTING YIELDS OF SPRUCE ON LOAMY PARENT MATERIALS IN BOREAL ONTARIO

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Regression equations which include geographic and physiographic variables demonstrate the significance of both in volume estimation. Regression coefficients for latitude, longitude and interactions generate volume surfaces showing why unbiased small equations lacking geographic variables may estimate volume poorly in different parts of boreal Ontario. Additional data would permit verification or correction of the surfaces.

L'inclusion de variables géographiques et physiographiques dans les équations de régression est la preuve de l'importance des unes et des autres dans le cubage. Les coefficients de régression pour la latitude, la longitude et leurs interactions donnent des surfaces de cubage qui montrent pourquoi, dans différentes parties de la région boréale de l'Ontario, de petites équations sans distorsion ou variables géographiques procurent une évaluation médiocre du volume de bois. Des données supplémentaires permettraient de contrôler ou de corriger ces surfaces.

INTRODUCTION

Certain portions of current regression studies based on the cull studies data reported by Morawski et al. (1958) will be presented here, specifically, those dealing with stands on well drained upland sites in the boreal mixedwood forests of Ontario. The evidence and most of the discussion will be restricted to either black spruce (*Picea mariana* [Mill.] B.S.P.) or white spruce (*P. glauca* [Moench] Voss) components in the plots from which those data were obtained.

Managers need small equations to keep measurement costs down in cruising and other sampling. They would also like to have groups of such small equations assembled into growth and yield models.

In an essentially non-technical form, the thesis will be presented that working with large equations provides our best hope of gaining sufficient understanding of underlying relationships to permit intelligent determination of which small equations should be used for any given purpose, regardless of whether the equations are to be used singly in different locations or are to be aggregated into models. Some of the advantages and disadvantages of using large equations will be illustrated and discussed. Some benefits of weighted regression will also be discussed.

The effect of geographic location on volume estimation will be demonstrated through maps derived from large equations.

MATERIALS AND METHODS

The cull studies data of Morawski et al. (1958) were obtained from destructively sampled 0.04 ha plots in stands selected as being operable. Each tree with a DBH greater than 8.89 cm had its diameter and height measured, its stump age recorded and its stem sectioned for determining gross total volume (GTV), gross merchantable volume and net merchantable volume. Only GTV is presented here, but the other two can also be estimated with slightly less precision.

For each plot, approximations of latitude and longitude were given, as were slope and aspect, if any; soil moisture regime, texture of the "parent material" and broad classes of soil depth were also determined. Some description of the soil horizons usually was provided. From these, two additional variables were derived, one for the texture of the "rooting zone", generally between the A horizons and the parent material (or discontinuity layer), and another for broad classes of compaction of these soil materials.

"Plot heights", similar to "top heights" but averaging the (up to) four tallest trees of any given species per plot (100/ha), were determined. Plot ages were estimated by rejecting obviously relict trees and apparently advanced-growth trees. Form factors, comparing the GTV of each tree to a paraboloid with the same height and with basal diameter equal to DBH, were calculated for each tree of any species component, then averaged harmonically for the four tallest trees, and for all trees, of that component.

Additional variables included stem frequencies, basal areas, average DBHs and transforms (squares and cubes) of, or interactions (e.g., height/age) between, other variables. A list of pertinent variables is given in Table 1.

To facilitate regression work with large equations, an interactive programming package has been written (Raymond 1980). It adapts much of Grosenbaugh's (1967) REX package so that the user is making all of the decisions and is constantly aware of the apparent contributions of all variables. It also appears to be the quickest and cheapest way of obtaining the "best" equations.

Table 1. Regression variables appearing in equations.

2. Basal area of all major species
3. Avg height " " " "
4. Frequency of species component
5. Basal area " " "
6. GTV " " "
9. Avg DBH " " "
10. Avg height " " "
11. All tree form factor "
12. "Plot height" "
13. Range in (12) "
14. Tallest 4 form factor "
15. Latitude
16. Longitude
17. Lat * Long
18. $\sqrt{\text{Lat * Long}}$
19. Lat/Long
20. Aspect

21. Slope %
25. Soil depth
26. Moisture regime
27. Soil compaction
28. Rooting zone texture
30. Square of (5)
31. (5) * (10)
32. (5) squared * (10)
33. (10) squared
34. (10) cubed
35. (10)/plot age
36. (5) * (12)
37. (5) squared * (12)
38. (12) squared
39. (12) cubed
40. (12)/plot age

RESULTS AND DISCUSSION

In a review of regression procedures, Hocking (1976) pointed out that the appropriateness of any regression equation depends upon its intended use and that many statisticians prefer residual (or error) mean square (or mean squared residual) as the selection criterion. Grosenbaugh states that "It is a figure of merit whose minimum flags a 'best bet'." Such a "best" equation may contain one or more variables that are individually not quite significant. However, when the intended use of the equation is for understanding relationships, those variables need not be rejected immediately.

More important than the fate of such variables is the possibility that either certain of the "significant" variables are of no real importance or certain groups of variables may suggest erroneous relationships. The latter situation can be clarified through examination of some of the results.

Since the data were given in Imperial units, these preliminary equations are as well. Conversion factors are provided in footnotes to the tables. GTV is given in cubic feet per 0.1 acre plot. The mean value for black spruce components on 41 plots was 104.96 cu. ft/plot or 73.44 cu. m/ha; for white spruce components on 32 plots it was 44.472 cu. ft/plot or 31.12 cu. m/ha.

The equation given in Table 2 is an almost-best equation similar to a best equation for unweighted black spruce except that all non-significant variables have been removed. A more familiar form for expressing the equation would be:

$$\begin{aligned}\mathrm{GTV} = {} & 26095.3+0.33551(4)-8.42057(5)+1.86651(9)+2.76904(10)\\ & +71.5834(11)+0.103832(13)+1057.22(15)+406.727(16)\\ & +4.28603(17)-1891.84(18)-14521.5(19)-2.42304(25)\\ & +1.62975(27)-2.20935(28)+0.479086(30)+0.442763(31)\\ & -0.0278324(33)-44.9745(35)+0.10283(36)-0.00650814(37)\\ & +38.7913(40)\end{aligned}$$

where the numbers within parentheses are the numbers of the variables given in Table 1. This equation estimates the GTV, in cubic feet, of the black spruce component in any 0.1 acre plot on loamy, parent materials for which measurements of the included variables are available. All of them are significant on the basis of their t-values. The results are roughly converted into cu. m/ha when multiplied by 0.7. This equation has 21 independent variables and estimates component GTV with an average precision of 1.61% (100 * SEE/avg GTV). However, Table 3, which is a table of residuals or errors in estimation, makes it clear that all of the largest percentage errors in estimation are related to the plots with the smallest component volumes. This is a direct consequence of the fact that the variation in component volumes increases with the size and volume of the component.

To counteract this, volume variances were calculated in a manner (cf. Raymond 1980) similar to that recommended by Cunia (1964), except that the hand-drawn curve for smoothing those variances was not then fitted to a small equation; the reciprocal of any curved value was used to "weight" each particular observation (or plot component description). Table 4 is an "almost-best" weighted equation containing 22 variables. Table 5 is the associated table of residuals. In these tables it can be seen that the worst percentage errors in estimation are both much smaller

Table 2. An "almost-best" unweighted regression equation estimating black spruce GTV.

```
14-AUG-80 FILE SP133
SB ON LOAMS--MOARAWSKI'S CULL STUDIES
X#      MEAN          ST DEV        R(XY)          REG CO        T VALUE
 4 0.17073E+02 0.22062E+02 0.84288E+00 0.335510E+00     3.1290
 5 0.42863E+01 0.48981E+01 0.98862E+00-0.842057E+01    -3.5568
 9 0.70288E+01 0.15905E+01 0.22956E-01 0.186651E+01     2.7765
10 0.51100E+02 0.97496E+01 0.34032E+00 0.276904E+01     7.0980
11 0.88624E+00 0.57946E-01-0.17148E+00 0.715834E+02     8.8733
13 0.83902E+01 0.78609E+01-0.16835E+00 0.103832E+00     2.0145
15 0.49066E+02 0.64250E+00-0.62283E-01 0.105722E+04     4.4899
16 0.86227E+02 0.28535E+01 0.52532E-01 0.406727E+03     4.8751
17 0.42316E+04 0.17809E+03 0.22373E-01 0.428603E+01     2.0119
18 0.65038E+02 0.13847E+01 0.20949E-01-0.189184E+04    -3.6634
19 0.56932E+00 0.15845E-01-0.83765E-01-0.145215E+05    -3.7126
25 0.13659E+01 0.62274E+00 0.13450E-01-0.242304E+01    -3.5341
27 0.20976E+01 0.12411E+01-0.21707E+00 0.162975E+01     3.8990
28 0.34878E+01 0.12474E+01 0.46294E+00-0.220935E+01    -5.1881
30 0.41779E+02 0.76135E+02 0.96793E+00 0.479086E+00     3.7337
31 0.23134E+03 0.27849E+03 0.99870E+00 0.442763E+00    15.8965
33 0.27039E+04 0.99990E+03 0.32314E+00-0.278324E-01    -6.7075
35 0.45495E+00 0.12126E+00 0.42446E-01-0.449745E+02    -2.5167
36 0.28077E+03 0.34749E+03 0.99749E+00 0.102830E+00     3.7070
37 0.28440E+04 0.53161E+04 0.97317E+00-0.650814E-02    -3.5090
40 0.51434E+00 0.14981E+00 0.24656E+00 0.387913E+02     2.5910
Y#
 6 0.10496E+03 0.12491E+03             0.260953E+05

R=.99996 RSQ=.99991 SEE=.16896E+01 ERRMS=.28547E+01 ERRSS=.54240E+02

DO YOU WANT AN ANOVA TABLE(Y/N)?- Y

ANOVA TABLE
  SOURCE       DF         SS               MS              F
REGRESSION     21.    0.624065E+06    0.297174E+05 10409.8464
ERROR          19.    0.542400E+02    0.285474E+01
TOTAL          40.    0.624119E+06
```

NOTE: All of the variables that are measurements are expressed in Imperial units. Conversions are: 1 in. = 2.54 cm, 1 ft = 30.48 cm, 1 sq. ft = 0.09 sq. m (approx.), 1 acre = 0.40 ha (approx.), 1 cu. ft = 0.03 cu. m (approx.) and 1 cu. ft/acre = 0.07 cu. m/ha (approx.).

Table 3. Table of residuals for the equation in Table 2.

```
OBS#   OBSERVED Y    ESTIMATED Y    OBSY-ESTY    %(O-E)/E
   1  0.11540E+03   0.11669E+03 -0.12935E+01    -1.108
   2  0.53200E+02   0.53044E+02  0.15631E+00     0.295
   3  0.12600E+02   0.11463E+02  0.11372E+01     9.921
   4  0.41200E+02   0.40648E+02  0.55248E+00     1.359
   5  0.20000E+02   0.20552E+02 -0.55247E+00    -2.688
   6  0.37300E+02   0.35484E+02  0.18163E+01     5.119
   7  0.29240E+03   0.29188E+03  0.51737E+00     0.177
   8  0.18270E+03   0.18278E+03 -0.81383E-01    -0.045
   9  0.21900E+02   0.23592E+02 -0.16917E+01    -7.171
  10  0.36410E+03   0.36296E+03  0.11423E+01     0.315
  11  0.37500E+02   0.38067E+02 -0.56679E+00    -1.489
  12  0.47300E+02   0.48436E+02 -0.11360E+01    -2.345
  13  0.35000E+01   0.66832E+01 -0.31832E+01   -47.630
  14  0.10750E+03   0.10692E+03  0.57957E+00     0.542
  15  0.81100E+02   0.83552E+02 -0.24522E+01    -2.935
  16  0.35100E+02   0.34744E+02  0.35556E+00     1.023
  17  0.20000E+01   0.26756E+01 -0.67560E+00   -25.251
  18  0.25300E+02   0.24641E+02  0.65945E+00     2.676
  19  0.43600E+02   0.43279E+02  0.32093E+00     0.742
  20  0.32200E+02   0.32163E+02  0.36858E-01     0.115
  21  0.29610E+03   0.29679E+03 -0.68501E+00    -0.231
  22  0.35160E+03   0.35088E+03  0.71823E+00     0.205
  23  0.11170E+03   0.11194E+03 -0.23552E+00    -0.210
  24  0.53500E+02   0.51980E+02  0.15200E+01     2.924
  25  0.76000E+01   0.70895E+01  0.51051E+00     7.201
  26  0.25800E+02   0.24738E+02  0.10619E+01     4.293
  27  0.31000E+01   0.16314E+01  0.14686E+01    90.016
  28  0.78000E+01   0.64347E+01  0.13653E+01    21.217
  29  0.60000E+01   0.47000E+01  0.13000E+01    27.660
  30  0.43000E+02   0.43977E+02 -0.97659E+00    -2.221
  31  0.90100E+02   0.90463E+02 -0.36256E+00    -0.401
  32  0.80500E+02   0.81729E+02 -0.12294E+01    -1.504
  33  0.38020E+03   0.38124E+03 -0.10427E+01    -0.273
  34  0.59600E+02   0.59426E+02  0.17397E+00     0.293
  35  0.67900E+02   0.67128E+02  0.77197E+00     1.150
  36  0.38400E+03   0.38557E+03 -0.15710E+01    -0.407
  37  0.56000E+01   0.71988E+01 -0.15988E+01   -22.209
  38  0.12040E+03   0.11881E+03  0.15864E+01     1.335
  39  0.48200E+02   0.48239E+02 -0.39089E-01    -0.081
  40  0.17280E+03   0.17217E+03  0.63185E+00     0.367
  41  0.43210E+03   0.43111E+03  0.99062E+00     0.230
```

NOTE: All of the variables that are measurements are expressed in Imperial units. Conversions are: 1 in. = 2.54 cm, 1 ft = 30.48 cm, 1 sq. ft = 0.09 sq. m (approx.), 1 acre = 0.40 ha (approx.), 1 cu. ft = 0.03 cu. m (approx.) and 1 cu. ft/acre = 0.07 cu. m/ha (approx.).

Table 4. An "almost-best" weighted regression equation estimating black spruce GTV.

```
14-AUG-80 FILE WT133
WEIGHTED SB ON LOAMS--MORAWSKI'S CULL STUDIES
X#      MEAN          ST DEV         R(XY)          REG CO       T VALUE
  3 0.57400E+02 0.62269E-01 0.22177E-01-0.888956E-01   -3.7516
  4 0.49999E+01 0.26416E-01 0.74150E+00 0.434015E+00    2.6787
  5 0.73999E+00 0.49347E-02 0.97062E+00-0.712702E+01   -2.3758
  9 0.51000E+01 0.88192E-02 0.25629E+00 0.158242E+01    3.2978
 10 0.34800E+02 0.65794E-01 0.23403E+00 0.775040E+01    6.9912
 11 0.91900E+00 0.48824E-03-0.27947E+00 0.108422E+03    5.5313
 12 0.36300E+02 0.65199E-01 0.38216E+00-0.830258E+00   -2.4182
 13 0.16000E+02 0.78795E-01 0.27620E+00 0.181232E+00    5.5111
 14 0.92300E+00 0.49356E-03-0.35839E+00-0.430756E+02   -2.5550
 16 0.82400E+02 0.27749E-01-0.19514E+00 0.737748E+02    5.8215
 17 0.39060E+04 0.22415E+01-0.18777E+00-0.580938E+01   -5.6858
 18 0.62500E+02 0.17473E-01-0.18779E+00 0.643791E+03    5.5551
 19 0.57500E+00 0.74228E-04 0.20155E+00 0.488407E+04    5.7118
 26 0.20000E+01 0.79585E-02 0.58559E-01-0.930957E+00   -5.2897
 27 0.10000E+01 0.96648E-02-0.16164E+00 0.804858E+00    2.9684
 32 0.19001E+02 0.24697E+01 0.79864E+00 0.334744E-01    7.4501
 33 0.12110E+04 0.59034E+01 0.24005E+00-0.120276E+00   -6.9606
 34 0.42145E+05 0.41231E+03 0.24828E+00 0.674779E-03    6.4007
 35 0.26800E+00 0.78688E-03 0.14305E+00-0.592940E+02   -2.2392
 36 0.26900E+02 0.30109E+00 0.99438E+00 0.446987E+00   10.4736
 37 0.20001E+02 0.30571E+01 0.79325E+00-0.271883E-01   -7.4424
 40 0.27900E+00 0.79440E-03 0.25045E+00 0.528344E+02    2.2040
Y#
  6 0.12600E+02 0.11426E+00             -0.266152E+05

R=.99983 RSQ=.99966 SEE=.12763E+00 ERRMS=.16288E-01 ERRSS=.29319E+00

DO YOU WANT AN ANOVA TABLE(Y/N)?- Y

ANOVA TABLE
  SOURCE       DF        SS             MS            F
REGRESSION    22.    0.870138E+03   0.395517E+02  2428.2316
ERROR         18.    0.293189E+00   0.162883E-01
TOTAL         40.    0.870431E+03
```

NOTE: All of the variables that are measurements are expressed in Imperial units. Conversions are: 1 in. = 2.54 cm, 1 ft = 30.48 cm, 1 sq. ft = 0.09 sq. m (approx.), 1 acre = 0.40 ha (approx.), 1 cu. ft = 0.03 cu. m (approx.) and 1 cu. ft/acre = 0.07 cu. m/ha (approx.).

Table 5. Table of residuals for the equation in Table 4.

```
OBS#   OBSERVED Y   ESTIMATED Y    OBSY-ESTY   %(O-E)/E
   1  0.11540E+03  0.11333E+03  0.20709E+01    1.827
   2  0.53200E+02  0.53909E+02 -0.70932E+00   -1.316
   3  0.12600E+02  0.12600E+02 -0.11304E-07   -0.000
   4  0.41200E+02  0.40989E+02  0.21094E+00    0.515
   5  0.20000E+02  0.20184E+02 -0.18422E+00   -0.913
   6  0.37300E+02  0.37484E+02 -0.18449E+00   -0.492
   7  0.29240E+03  0.29495E+03 -0.25515E+01   -0.865
   8  0.18270E+03  0.18243E+03  0.27122E+00    0.149
   9  0.21900E+02  0.22026E+02 -0.12575E+00   -0.571
  10  0.36410E+03  0.35865E+03  0.54463E+01    1.519
  11  0.37500E+02  0.36717E+02  0.78252E+00    2.131
  12  0.47300E+02  0.47732E+02 -0.43225E+00   -0.906
  13  0.35000E+01  0.35505E+01 -0.50484E-01   -1.422
  14  0.10750E+03  0.10948E+03 -0.19834E+01   -1.812
  15  0.81100E+02  0.82775E+02 -0.16751E+01   -2.024
  16  0.35100E+02  0.35131E+02 -0.31008E-01   -0.088
  17  0.20000E+01  0.20059E+01 -0.58568E-02   -0.292
  18  0.25300E+02  0.25210E+02  0.89859E-01    0.356
  19  0.43600E+02  0.43439E+02  0.16103E+00    0.371
  20  0.32200E+02  0.32352E+02 -0.15210E+00   -0.470
  21  0.29610E+03  0.29568E+03  0.41749E+00    0.141
  22  0.35160E+03  0.35441E+03 -0.28121E+01   -0.793
  23  0.11170E+03  0.10853E+03  0.31749E+01    2.925
  24  0.53500E+02  0.54072E+02 -0.57176E+00   -1.057
  25  0.76000E+01  0.77573E+01 -0.15728E+00   -2.028
  26  0.25800E+02  0.25274E+02  0.52632E+00    2.082
  27  0.31000E+01  0.29750E+01  0.12496E+00    4.200
  28  0.78000E+01  0.76412E+01  0.15875E+00    2.078
  29  0.60000E+01  0.60752E+01 -0.75234E-01   -1.238
  30  0.43000E+02  0.44560E+02 -0.15595E+01   -3.500
  31  0.90100E+02  0.93165E+02 -0.30648E+01   -3.290
  32  0.80500E+02  0.80113E+02  0.38732E+00    0.483
  33  0.38020E+03  0.37884E+03  0.13579E+01    0.358
  34  0.59600E+02  0.58391E+02  0.12087E+01    2.070
  35  0.67900E+02  0.66349E+02  0.15511E+01    2.338
  36  0.38400E+03  0.39234E+03 -0.83412E+01   -2.126
  37  0.56000E+01  0.56178E+01 -0.17848E-01   -0.318
  38  0.12040E+03  0.11526E+03  0.51434E+01    4.463
  39  0.48200E+02  0.48879E+02 -0.67858E+00   -1.388
  40  0.17280E+03  0.17353E+03 -0.72529E+00   -0.418
  41  0.43210E+03  0.42762E+03  0.44812E+01    1.048

IN ORIGINAL UNITS: SEE=.33532E+01 ERRMS=.11244E+02 ERRSS=.20239E+03
```

NOTE: All of the variables that are measurements are expressed in Imperial units. Conversions are: 1 in. = 2.54 cm, 1 ft = 30.48 cm, 1 sq. ft = 0.09 sq. m (approx.), 1 acre = 0.40 ha (approx.), 1 cu. ft = 0.03 cu. m (approx.) and 1 cu. ft/acre = 0.07 cu. m/ha (approx.).

and more evenly distributed over the range of volume magnitudes than was true without weighting.

If we want fairly precise estimates of volume for components that are often small, weighted regression is better. If we are interested only in essentially pure stands of a given species, unweighted regression may be better.

The almost-best equations for white spruce are given in Tables 6 and 7 for unweighted and weighted regressions, respectively. In these tables, aspect (var. 20), slope (var. 21), moisture regime (var. 26) and compaction (var. 27) all appear to be important[1] in the precise estimation of white spruce GTV. Also, latitude (var. 15), longitude (var. 16) and their interactions (vars. 17, 18, 19) appear quite important.

In the black spruce plots, soil moisture regime and compaction were significant in the weighted regression, while soil depth (var. 25), compaction and rooting-zone texture (var. 28) were significant in the unweighted regression. Longitude and the latitude-longitude interactions appeared quite important in both, but latitude was included in only the unweighted equation.

The influence of geographic location as expressed by latitude, longitude and interactions was explored by varying latitude and longitude, using all five regression coefficients, while holding all other included variables constant at the levels of their mean values. This produces a surface on which GTV varies with geographic location. Isopleths can then be drawn connecting points with common values.

This was done for the unweighted black spruce equation in Table 2, and the result can be seen in Figure 1. Where we were able to move the plot of average structure to various points within the approximate rectangle determined by the extremes of latitude and longitude from the sampling, each isopleth represents a change of 5 cu. m/ha. Each of the six circles in the figure represents a locus of plot locations. That number of loci is too small to inspire great confidence in the results.

On the other hand, the pattern of isopleths appears to relate fairly well to the combined patterns of annual precipitation and mean daily air temperature. Furthermore, the early indication is that, for all major boreal species except white spruce, comparable surfaces will be obtained from each of the parent-material textures sampled sufficiently to support exploration of large equations. This inspires greater confidence. However, additional sample plots from the essentially unsampled portions of the boreal forest will be required for assurance that both the patterns and the isopleth levels are reasonably correct.

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[1] The importance of the contribution by any variable can be judged tentatively by considering the magnitude of its regression coefficient (REG CO) in relation to a one-unit change in the value of that variable.

Table 6. An "almost-best" unweighted regression equation estimating white spruce GTV.

```
14-AUG-80 FILE SP123
SW ON LOAMS--MORAWSKI'S CULL STUDIES
X#      MEAN          ST DEV        R(XY)         REG CO        T VALUE
 4 0.40938E+01 0.34952E+01 0.32026E+00-0.714018E+01 -10.5391
 5 0.16659E+01 0.11766E+01 0.96468E+00 0.453038E+02   5.7789
 9 0.89112E+01 0.34687E+01 0.58632E+00-0.394565E+01  -7.3321
11 0.88800E+00 0.77468E-01-0.39604E+00-0.152021E+03  -4.1516
12 0.55525E+02 0.17582E+02 0.68769E+00-0.262445E+01  -4.7792
13 0.17250E+02 0.14835E+02 0.20247E+00 0.152827E+00   5.5695
14 0.87762E+00 0.71009E-01-0.45029E+00 0.256246E+03   6.4437
15 0.49228E+02 0.63002E+00 0.83876E-01 0.237699E+03   3.9236
16 0.86378E+02 0.23603E+01 0.28338E-01 0.145697E+03   4.0210
17 0.42526E+04 0.14819E+03 0.52425E-01-0.716912E+01  -4.9941
18 0.65204E+02 0.11531E+01 0.52967E-01 0.540609E+03   4.5167
20 0.93750E-01 0.77707E+00-0.16064E+00 0.362501E+01   6.2781
21 0.43438E+01 0.39071E+01 0.86465E-01 0.346417E+00   3.7755
26 0.26250E+01 0.11570E+01-0.66284E-01-0.998970E+00  -2.4854
27 0.23750E+01 0.11288E+01 0.60026E-01 0.182928E+01   4.7860
30 0.41162E+01 0.47991E+01 0.94667E+00-0.697316E+01  -3.3827
31 0.96966E+02 0.83143E+02 0.97402E+00-0.454937E+01  -4.2636
32 0.24916E+03 0.31324E+03 0.96611E+00 0.671885E+00   3.2315
33 0.31199E+04 0.21007E+04 0.53654E+00-0.102325E+00  -3.9497
34 0.20137E+06 0.20073E+06 0.49806E+00 0.184687E-02   7.4127
36 0.10394E+03 0.89243E+02 0.98805E+00 0.414722E+01   4.1397
37 0.27059E+03 0.34054E+03 0.96703E+00-0.490836E+00  -2.5241
38 0.33824E+04 0.20653E+04 0.65799E+00 0.173968E+00   5.7809
39 0.22252E+06 0.19783E+06 0.61616E+00-0.227238E-02  -8.0990
Y#
 6 0.44472E+02 0.36105E+02             -0.290972E+05

R=.99992 RSQ=.99984 SEE=.97439E+00 ERRMS=.94943E+00 ERRSS=.66460E+01

DO YOU WANT AN ANOVA TABLE(Y/N)?- Y

ANOVA TABLE
  SOURCE       DF        SS             MS              F
REGRESSION     24.   0.404038E+05   0.168349E+04  1773.1624
ERROR           7.   0.664600E+01   0.949428E+00
TOTAL          31.   0.404104E+05
```

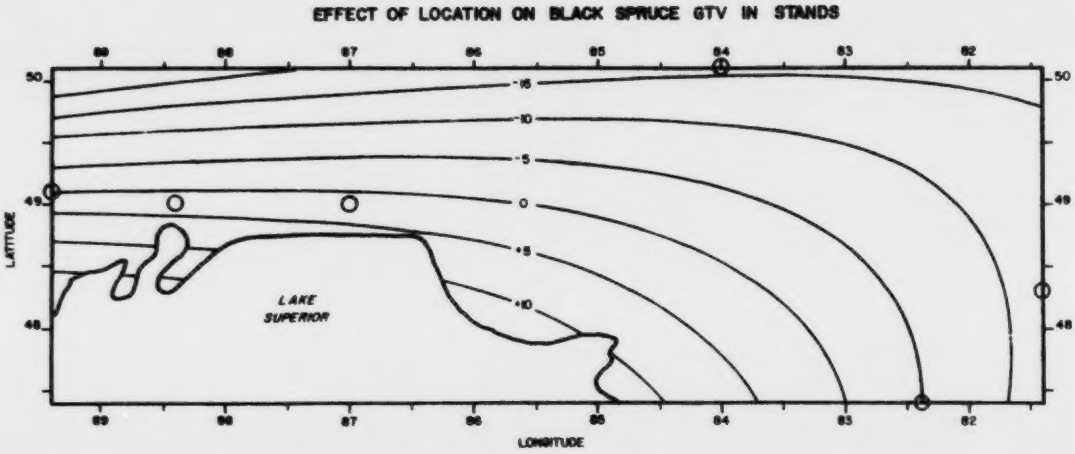
NOTE: All of the variables that are measurements are expressed in Imperial units. Conversions are: 1 in. = 2.54 cm, 1 ft = 30.48 cm, 1 sq. ft = 0.09 sq. m (approx.), 1 acre = 0.40 ha (approx.), 1 cu. ft = 0.03 cu. m (approx.) and 1 cu. ft/acre = 0.07 cu. m/ha (approx.).

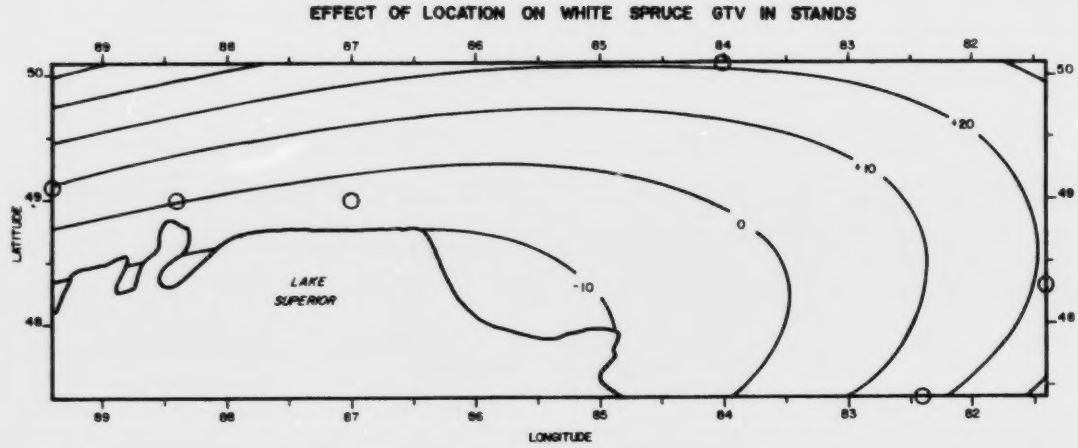
Table 7. An "almost-best" weighted regression equation estimating white spruce GTV.

```
14-AUG-80 FILE WT123
WEIGHTED SW ON LOAMS--MORAWSKI'S CULL STUDIES
X#     MEAN         ST DEV       R(XY)         REG CO      T VALUE
 2 0.13848E+02 0.49867E+01-0.41773E-01 0.545178E+00   4.8756
 3 0.61608E+02 0.11190E+02-0.12978E+00-0.205789E+00  -5.1488
 4 0.23477E+01 0.29403E+01 0.50605E+00-0.428202E+01  -8.4067
 5 0.54384E+00 0.91220E+00 0.97216E+00 0.318170E+02   6.0289
 9 0.61979E+01 0.33488E+01 0.67788E+00-0.403552E+01  -7.8634
11 0.91642E+00 0.80410E-01-0.27241E+00 0.667297E+02   8.9120
15 0.49230E+02 0.10204E+01-0.15572E-01 0.106095E+04   6.1886
16 0.86743E+02 0.32500E+01-0.11726E+00 0.320845E+03   5.3507
17 0.42707E+04 0.21514E+03-0.93518E-01 0.122780E+02   6.3393
18 0.65343E+02 0.16727E+01-0.92761E-01-0.280233E+04  -6.8517
19 0.56754E+00 0.18724E-01 0.13032E+00-0.202609E+05  -6.7080
20 0.87323E-02 0.13493E+01 0.96901E-01 0.210785E+01   5.2276
26 0.20436E+01 0.15242E+01 0.37534E+00 0.243211E+01   5.1623
27 0.24884E+01 0.19214E+01-0.78738E-01 0.251533E+01   6.6022
30 0.66308E+00 0.27711E+01 0.92152E+00-0.623098E+01  -3.9014
31 0.24930E+02 0.56420E+02 0.98572E+00-0.261667E+01  -7.3937
32 0.35191E+02 0.16857E+03 0.92006E+00 0.650013E-01   2.4822
34 0.80041E+05 0.17203E+06 0.58214E+00 0.589718E-03   6.8942
35 0.33863E+00 0.18756E+00 0.68445E+00 0.997792E+02   3.1880
36 0.25990E+02 0.60631E+02 0.99100E+00 0.278059E+01   8.8343
38 0.16820E+04 0.20617E+04 0.68333E+00 0.115983E-01   5.8455
39 0.83427E+05 0.17427E+06 0.65175E+00-0.654617E-03  -6.8201
40 0.34416E+00 0.20162E+00 0.73122E+00-0.108764E+03  -3.4681
Y#
 6 0.11688E+02 0.25459E+02             0.620634E+05

R=.99988 RSQ=.99976 SEE=.12481E+00 ERRMS=.15577E-01 ERRSS=.12461E+00

DO YOU WANT AN ANOVA TABLE(Y/N)?- Y

ANOVA TABLE
  SOURCE       DF        SS             MS            F
REGRESSION     23.   0.514818E+03   0.223834E+02  1436.9863
ERROR           8.   0.124613E+00   0.155766E-01
TOTAL          31.   0.514943E+03
```

NOTE: All of the variables that are measurements are expressed in Imperial units. Conversions are: 1 in. = 2.54 cm, 1 ft = 30.48 cm, 1 sq. ft = 0.09 sq. m (approx.), 1 acre = 0.40 ha (approx.), 1 cu. ft = 0.03 cu. m (approx.) and 1 cu. ft/acre = 0.07 cu m/ha (approx.).

Analogous isopleths for the unweighted white spruce surface can be observed in Figure 2. In this case, they differ by 10 cu. m/ha. However, the important thing to note is that they increase or decrease in the opposite directions to those of black spruce. That is, the results for white spruce appear to be erroneous.


EFFECT OF LOCATION ON BLACK SPRUCE GTV IN STANDS
89
88
87
86
85
84
83
82
50
49
48
LATITUDE
LONGITUDE
-15
-10
-5
0
+5
+10
LAKE SUPERIOR


EFFECT OF LOCATION ON WHITE SPRUCE GTV IN STANDS
89
88
87
86
85
84
83
82
50
49
48
LATITUDE
LONGITUDE
+20
+10
0
-10
LAKE SUPERIOR

Figures 1 and 2. GTV surfaces as affected by latitude and longitude, for black spruce and white spruce components, respectively. Six circles indicate sampling loci. Isopleths define the surfaces. In Figure 1, which appears typical for most major species on all textures of parent material, the isopleths are 5 cu. m/ha apart. In Figure 2, they are 10 cu. m/ha apart.

A possible explanation is as follows: The diameter-class distribution of white spruce stems is usually very disjointed in the cull studies plots. A typical white spruce component of a plot will contain a few stems of very large DBH, a few of very small DBH, a few of an intermediate DBH, or any combination of those three conditions. The very presence of white spruce is almost a guarantee of stand disturbance and non-normality in those plots; to a lesser extent this tends to apply to white birch (*Betula papyrifera* Marsh.) and balsam fir (*Abies balsamea* [L.] Mill.) also. The soils under the white spruce plots were often irregular in their profiles, with alternating series of B and C horizons. Also, they often appeared to have been called loams because they contained layers of sands alternating with layers of silts or clays, but no purely loamy materials. The result may be correct, but this appears unlikely.

Such aberrations often can be resolved by stratifying the observations according to the structures of the species component in question. This almost demands additional data here. Alternatively, mild biasing through application of a ridge regression will often change the signs of certain coefficients (cf. Mitchell and Hann 1979, Raymond 1980); this might also reverse the signs on the isopleths.

Now, it would be ridiculous to expect managers to support the cost of measuring all of the variables included in such large equations every time they want estimates based on sampling. On the other hand, it should be clear that any small, province-wide equation may provide badly biased estimates in different localities, even though an estimate for the whole of boreal Ontario might be completely unbiased if the same equation were used. Each area manager needs either a small equation that is locally unbiased or a cheap, simple means of correcting for local bias when a standard small equation is used. It is submitted that examination of large equations derived from adequate data is the best means of resolving the problem, no matter which of the options is chosen. There ought to be sufficient information in the tables to permit technical validation of the procedures by any statistically oriented manager or consultant.

In any case, it is hoped that the provisional results presented here will stimulate at least a few of you managers to consider the potential usefulness of large equations as a means of arriving at the small equations you need and to adapt them to your particular area of responsibility. If you do consider using such equations, ask me to help you produce them; don't ask me to produce them for you.

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PRESENT UTILIZATION OF SPECIES IN THE BOREAL MIXEDWOOD FORESTS IN ONTARIO:

INDUSTRIAL PERSPECTIVE

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Yields per unit area are higher from boreal mixedwood stands than from black spruce stands. In addition, mixedwood stands are attractive for the logging industry because of high-value products, year-round logging, and economies in road access. Major unresolved problems in boreal mixedwood stands are lack of markets for hardwood species and increased hardwood components and balsam fir in succeeding stands.

Le rendement par unité de surface est plus élevé dans les peuplements mélangés de la forêt boréale que dans ceux d'Épinette noire. En outre, l'industrie du bois est intéressée par les peuplements mélangés en raison de la valeur élevée de ses produits, de la possibilité de les exploiter à l'année et des économies réalisées en ce qui regarde l'accès des routes. Dans les peuplements mélangés de la forêt boréale, les principales difficultés à surmonter sont le manque de débouchés pour les essences feuillues et l'accroissement de la proportion des feuillus et du Sapin baumier dans les peuplements subséquents.

Forest harvesting and subsequent management techniques for forest replenishment should not be treated in isolation. The degree of forest utilization can have a powerful effect upon economically advantageous silvicultural treatments that are intended chiefly to establish the future crop.

Before we can discuss utilization intelligently, we must know what we are dealing with. What is a boreal mixedwood forest? There seems to be no question that it is a forest which is complex and variable. Species composition appears to be related in some way to site and to the dynamics of stand development. Apart from that I will not attempt to define mixedwood forest except to say that, as far as utilization is concerned, it is important to be able to identify species composition with reasonable precision.

The Forest Resource Inventory system does not provide a quantitative or qualitative basis for synthesizing the dimensions of the component parts of mixedwood stands. Therefore, I have dug into my bag of tricks and dusted off the conventional description of the mixedwood cover type.

The mixedwood cover type consists of 25%-75% by volume of softwood species--spruce (*Picea* spp.), jack pine (*Pinus banksiana* Lamb.) and balsam fir (*Abies balsamea* [L.] Mill.) with the remainder hardwoods--principally trembling aspen (*Populus tremuloides* Michx.) and white birch (*Betula papyrifera* Marsh.).

In the previous paragraphs I described an average or representative mixedwood stand, and I will now discuss this stand in terms of utilization.

It should be noted that the data provided are representative for mixedwood stands in the eastern portion of the North Central Region, an area with which I am quite familiar, and these stands may or may not resemble those in other areas of northern Ontario's boreal forest.

Let us for a moment examine the combined stand/stock tables (Tables 1 and 2) and evaluate the assets and liabilities of the representative mixedwood stand.

Table 1. Representative natural mixedwood stands.[a]

Species	Yield (m^3/ha)	%	Stems/ha	%	Avg. no. of trees/m^3
Black spruce	45.8	17.08	173.6	24.6	49.84
White spruce	25.0	9.32	39.8	5.6	20.91
Balsam fir	30.7	11.46	185.0	26.2	79.16
Jack pine	18.5	6.88	32.9	4.6	23.41
Other conifers	0.5	.21	1.7	.2	-
Total conifers	120.5	44.95	433.0	61.2	42.23
Trembling aspen	88.8	33.15	105.2	14.9	15.55
Balsam poplar	12.3	4.58	16.1	2.3	17.18
White birch	46.4	17.31	152.4	21.6	43.17
Total hardwoods	147.5	55.05	273.7	38.8	24.39
Merchantable conifers	119.9	44.75	431.3	61.0	47.26
Merchantable conifers plus aspen	208.8	77.90	536.5	75.9	33.78
TOTAL CONIFERS AND HARDWOODS	268.0	100.00	708.7	100.0	34.66

[a] Basis - approximately 2,000 plots, each .05 ha in size on American Can Canada Inc. limits in the Manitouwadge and Caramat areas of northern Ontario.

Table 2. Comparison of mixedwood and black spruce stands.

	Yield (m^3/ha)		Stems/ha		Trees per m^3	
	Mixedwood	Sb	Mixedwood	Sb	Mixedwood	Sb
Merchantable conifers	119.9	174.1	431.3	1010.0	47.26	76.22
Merchantable conifers plus aspen	208.8	177.3	536.5	1015.7	33.78	75.28
TOTAL OF ALL TREES	268.0	188.4	708.7	1058.9	34.66	73.83

Assets

(1) Although the figures in the tables do not explicitly demonstrate the point, it is important to recognize the feature of site type. Boreal mixedwood stands develop mostly on upland sites which can be harvested during the frost-free season of the year. In order to balance logging activity and delivery scheduling to ensure year-round employment opportunities, the feature of seasonality must be stressed.

(2) Probably because of site-related factors, average mixedwood stands will provide about 268 m^3 per ha for all species, whereas the average black spruce (*Picea mariana* [Mill.] B.S.P.) stand will yield 188 m^3 per ha (Table 2). This represents an increase of 43% in total fibre yield.

As far as the merchantable conifer component of the mixedwood cover type is concerned, the yield is approximately 120 m^3 per ha in comparison with 174 m^3 per ha from black spruce stands. However, if markets were available for aspen, the potential yield of 209 m^3 per ha from the mixedwoods would become even more attractive. A gain of 18% in fibre yield is obtained in mixedwood stands (conifer plus aspen) in comparison with the average black spruce stand (Table 2).

(3) An important parameter used in the preparation of harvesting plans and budgets is the number of trees required to produce a cubic metre of wood. It is this operating factor that guides most harvesting decisions and enables us to work out the economics of the operation in terms of pulpwood productivity levels, other more valuable byproducts, sawlogs or veneer, and harvesting methods.

An examination of Table 2 reveals that there are significant gains in productivity in mixedwood stands in comparison with lowland black spruce stands. Stems are larger, though more dispersed, in the conifer component than in the representative black spruce stand (47 as opposed to 76 trees per m^3). A significant gain in productivity would be realized if aspen could be utilized. It is important to note that, because of wood size, the mixedwood stands represent significant opportunities in terms of extraction of sawlogs and veneer material. I would venture to say that 50%-60% of all wood utilized in the sawmill industry and almost all of the material used in the plywood/veneer and flakeboard industries are derived from mixedwood stands.

(4) Another asset, one not directly related to stand composition and utilization, is the fact that road construction on sites occupied by mixedwood stands is less difficult and consequently more economical. This feature is related to site or topography but is extremely important in planning for year-round harvesting and delivery of forest products to conversion plants.

Liabilities

These, for the most part, are related to management techniques for restoring forest productivity in mixedwood stands.

(1) Balsam fir is a major component of the mixedwood stand. However, it is generally smaller in diameter and achieves less height growth than other conifers, probably because of the dynamics of the species and the successional nature of the stand. Balsam fir is not a particularly stable component in that it is very susceptible to insect and disease damage.

Table 1 indicates that there are 185 merchantable balsam fir stems per hectare developing about 30.7 m^3 of merchantable wood. However, this is probably a low estimate as there are likely many more stems which have not achieved merchantability. Balsam fir is a relatively short-lived species which begins to decay quite early. It is also susceptible to attack by the spruce budworm. Because of small tree size and prolific advance growth of unmerchantable stems, logging productivity is often impaired. Similarly, residual fir stems left after logging operations present problems for post-harvest silvicultural treatment.

(2) Mixedwood stands with a large component of white birch are usually situated on the lower end of the site-type spectrum. These stands are found growing in shallower and less productive soils. Utilization of birch is a problem primarily because of poor tree form, decadence, logging difficulties and lack of markets. However, stands with a large birch component are less of a problem in the context of post-harvest treatment.

(3) The aspen component represents the principal problem, and consequently the primary challenge, as far as subsequent silvicultural treatment of mixedwood stands is concerned. The root of the problem is the

ability of the species to propagate vegetatively, and in great abundance. Because of the vigorous development of aspen sucker growth, any species naturally or artificially introduced into the stand will have considerable competition for survival. I am not convinced that complete utilization of aspen in mixedwood stands will result in high-yield, high-component conifer forests for the future. Indeed, the opposite may be true. Clearcutting or complete utilization of the aspen component may in fact be the technique which will change the mixedwood stand of today into the hardwood stand of tomorrow.

I have conducted you on a quick and dirty tour through the boreal mixedwood forest, as I understand it. In summary, this forest represents the following:

- good year-round wood extraction opportunities
- better than average soil productivity resulting in good timber yields
- material of better than average size favoring highly valued sawlogs and veneer material and gains in efficiency of logging operations
- land form amenable to all-season logging operations and economical road building opportunities
- problems in restoring the long-fibre component (conifers) for the future crop.

It has become fashionable, it seems, to resolve rather complex problems in a simplistic manner. In this regard I will offer a few words of caution.

I have been told, and we shall probably hear it at this symposium, that the obvious remedy for "high grading" because of a lack of markets is the restriction of harvesting until markets permit complete utilization, which supposedly will provide a solution to the dilemma of post--harvest treatment. I must agree that complete utilization does make sense in the context of wood harvesting economics, provided that the proper markets are in place.

Ideally, if markets were available, there would be no losers. The forest industry would benefit in terms of increased yield, increased logging productivity and improved product flow, and this would result in a decrease in unit costs of delivered wood. The government, too, would prosper as a result of increased revenues from Crown timber.

Everyone a winner? No, unfortunately the concept of complete utilization will probably conflict with the objective of recreating a mixedwood forest with a reasonable coniferous component.

The culprit? You guessed it--aspen and its propensity to "shoot from the root" in such profusion.

To place "fences" around mixedwood stands by restricting harvesting activity just does *not* make practical sense; furthermore, it will cause significant economic and operational hardships to conversion plants dependent upon sawlogs and conifer material for veneer. Inherent in this strategy, too, is the general effect of reducing conifer allowable cuts and disrupting year-round employment in logging activity.

If we refer to Table 1 in which the average conifer component in the mixedwood stand represents 45% of total yield, it does not take much imagination to contemplate the economic and social effects of undertaking a policy of restricting harvesting activity in this type of stand. So much for the "restriction option".

I would now like to address the "encouragement" alternative. Implicit in this alternative is the assurance that the future stand will be no worse, and, it is hoped, will be a lot better than the original stand in terms of coniferous content. The idea of encouragement appeals to me, but in this instance gives no cause for exultation. Utilization of aspen in mixedwood stands with even a modest aspen composition will conflict with the basic objective of increased future conifer yield, unless the forest manager is prepared to invest heavily in site preparation and subsequent tending operations.

What I am trying to say, and it may be worth reiterating, is that complete utilization is probably not the solution to the problem of restoring timber values in mixedwood stands. There must be a better way.

At the risk of walking where angels fear to tread--particularly in the domain of the silviculturist--I would like to express some general views on options that should be considered in attempts to increase the value of timber in mixedwood stands.

(1) The descriptive composition of the *original* stand from the standpoints of yield, stocking and site productivity should give a good preliminary clue as to what needs to be done. It is from this base that both harvesting and silvicultural decisions must be made. Inasmuch as the forest manager must simulate his perceptions of future stand configuration, it is this type of information that provides the pattern upon which he must base his silvicultural decisions.

(2) The utilization feature must be thoroughly examined in both the biological and the economic sense. This must be rationalized in such a way that present and projected future demand will be maximized without impairment of the development of the future stand.

(3) Post-harvest management technique should be evaluated within a framework of practical economics. Silvicultural investment decisions should be made on the basis of maximizing returns and setting value priorities. The better the opportunity the better the chance for investment capital.

In conclusion, I would like to say that there are no simple solutions to the problems associated with management of the boreal mixedwood forests. Utilization or lack of utilization has been presented as the villain in the piece. It is not quite that simple. We need solutions to complex and challenging problems, and those solutions will require a concentrated effort by all who are connected in any way with the mixedwood forests of our country.

PRESENT UTILIZATION OF SPECIES IN THE BOREAL MIXEDWOOD FOREST OF ONTARIO: A MANAGEMENT PERSPECTIVE

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This paper presents a management view of current utilization of boreal mixedwood species in Ontario, and of ways in which management practices can be improved. It is based on the author's 30 years of experience working with these species.

La présente communication brosse une perspective d'aménagement de l'exploitation actuelle des essences dans la forêt boréale mélangée de l'Ontario et propose des façons de l'améliorer. Cette perspective se fonde sur l'expérience de l'auteur qui travaille depuis 30 ans sur ces essences.

In recent years there have been a number of conferences, workshops, symposia, etc., which have identified utilization in the boreal forest as a major concern. Although this concern relates to the total forest area, the principal problems are connected with the boreal mixedwood forest as defined by the organizers of this symposium.

I have been asked to express a management view of present utilization. This view will be based upon over 30 years of observation across the forest of northern Ontario. I cannot guarantee that it will represent the view of all managers in the Ontario Ministry of Natural Resources (OMNR) but I expect that there will not be too much disagreement. It is primarily the view of a concerned forester who often feels that he has failed to have the impact for change that he should have had.

I will be talking primarily about ways in which we must improve forest management practices if industry and government are to fulfil their mandates responsibly. In other words, I will be talking about proper forest management on behalf of the owners of the forest estate--the people of Ontario and of Canada.

I should like to speak about current utilization under three main headings:

1) utilization of coniferous species for which markets exist
2) utilization of deciduous species for which markets are limited at present
3) over-utilization of the land base by operating style and cutting concentration.

I will deal with each issue separately, although this will be difficult because good forest management must include all aspects of utilization.

Utilization of coniferous species is generally good in comparison with utilization of deciduous species. Almost all conifers are usable in the existing processing plants. There is, however, considerable room for improvement. The degree to which felled trees are utilized varies dramatically depending upon tree size, operating systems, time of year and, perhaps most important of all, the attitude of operating staff and the vigilance and concern of the local OMNR managers. The volume left behind on each operation varies from a fraction of a cord per ha to several cords per ha. I am speaking now only of wood not utilized according to the standards set in the Crown Timber Act. There is a considerable volume of wood that lies outside these parameters.

Utilization is often dictated by the logging system in use. Some are flexible, as the old lumberjack used to be, and can adapt to difficult situations; others are not flexible. When wood is not properly utilized it is almost always for economic reasons. Every new step or new action has a cost. As a rule, however, only short-term costs are considered. The camp foreman is concerned primarily with the current year's cost. But what of the cost in the future to obtain replacement wood for the wood not properly used now? This factor is seldom brought into the equation at any level.

We are rapidly reaching the point at which we are being compelled to use every kilogram of fibre that can practicably be harvested. Costs control results but often the costs considered are for operations based on present systems only. What are required now are imaginative and innovative actions, and the foresight to view current constraints merely as problems to be solved in order to meet a higher, long-term objective.

Small wood has not been used extensively by pulp mills for a number of reasons, but principally because it will not go through the drum barkers properly. How much effort has gone into developing a different barking method? None, to my knowledge.

Another reason small wood is not harvested is that the logging systems in use cannot handle it efficiently. Hence, the smaller trees in most mature black spruce (*Picea mariana* [Mill.] B.S.P.) stands remain unharvested. Not only are they not used, but they are occupying land that may not produce a crop for the next rotation unless the trees themselves survive for this period.

At the silvicultural equipment exhibition held in Thunder Bay this past June a film was shown on logging in Finland. What impressed me most when I saw the film was that the Finnish had obviously developed equipment to cope with very special logging situations. Admittedly, Finnish forests are under intensive management and conditions are more uniform. However, we have sufficiently large areas with similar conditions to warrant our looking at the development of special equipment to make harvesting in these conditions practicable.

Balsam fir (*Abies balsamea* [L.] Mill.) presents a special problem. All mill operators insist that they will use balsam fir when they encounter it, but the Ministry must exert constant pressure to ensure that they do.

To my mind, balsam fir presents a double-barrelled problem. For one thing, the mill operators would prefer not to see balsam fir at all, especially if it exceeds a fairly low percentage of the furnish. (This is primarily an operating logistics problem which can be costly under existing systems, but not impossible to deal with.) For another thing, the trees are often small, brittle and difficult to harvest with large mechanical systems.

If we do not harvest all the balsam fir during this first harvest of the natural forest, we will continue to convert large areas to the balsam fir working group. One recent survey showed that the balsam fir working group constitutes 65% of old cutovers. We therefore have a serious problem in terms of potential damage by the spruce budworm, which is now destroying whole age classes from our forest inventory. Vast areas of old cuts and overmature upland cover types are now 20- to 40-year-old balsam fir. These stands are for the most part close to existing mills and in accessed areas. They could provide volumes of cheaper wood at a time when industry badly needs it. If, by some miracle, they survive an attack by the spruce budworm, we will need different logging systems so that we can realize the full fibre potential of these stands, as they tend to be uneven aged, with a large percentage of small trees.

Balsam fir, if properly managed, has the potential to produce very high yields per unit area. To date, we have not seriously considered it as a management option. Control of stocking would appear to be the critical factor. In our plans for the management of our boreal mixedwood forest we must give careful consideration to the way in which we will deal with balsam fir, from eradication to maximum fibre production. We cannot continue to ignore it, and we cannot permit its percentage of the forest cover to increase except under intensive management.

To improve the utilization of all available conifers from present cuts will require a dramatic change in our thinking. Solutions will not be found unless industry recognizes that there is something to be gained. Most industrial personnel do not realize that significant recoveries per unit area are possible. Recoveries must be such that the full stem volume of all trees arrives at the mill. Slasher sites should be clean, and so should the cutover lands. We have a long way to go.

The second main area of concern with respect to utilization in the boreal mixedwood forest is that of the deciduous content, which is utilized either not at all or only in part. The deciduous content of the boreal forest represents approximately 25 to 30 percent of the merchantable volume and a considerably higher percentage of the gross total volume. It is the gross total volume which is of major concern.

A large percentage of our conifer volume is recovered from stands which contain a certain percentage of deciduous trees. The percentage will vary from as low as 10% to as high as 80%. When no deciduous trees are harvested at all the cutover areas may be anything from virtual clearcuts to what eventually becomes a pure hardwood stand. These pose many problems, all of which have been discussed numerous times before.

In a world which, according to all predictions, will eventually require the total production of its forested lands, a major concern within the forestry community should be the wood which is left to decay. Even those stands with a considerable volume of hardwood remaining will seldom be harvested. Many of the stands have deteriorated so badly after 5 to 10 years that it is no longer economically feasible to recover the residue. Not only is the hardwood fibre lost but these forest lands, which are often the most productive of the boreal forest, are effectively taken out of production for extended periods. They cannot be regenerated to conifers at a reasonable cost and are doomed to break up, fill in with brush and probably return to pure hardwood stands. Unfortunately, the hardwood is often off site.

Aspen (*Populus* spp.) is the major deciduous tree utilized at present. Even where aspen is in reasonable demand, however, such as in the North Central Region, utilization still leaves much to be desired. The demand is primarily for waferboard, although some 200,000 m^3 are used annually for peeling. Where waferboard is the major product the specifications are often such that large-diameter bolts are rejected and only top-quality bolts are used. With a demand for peelers in the same area, the solution would appear to be obvious. However, where peelers are not required, bolts that are too large for waferboard are often left behind in any case. This situation must be corrected. It is unlikely that peelers will be produced from the second crop of aspen but we should at least recover them from the first crop rather than leave them on the ground. The cost may be high, but it can be reduced if a little common sense is used. Licensees must recognize that they are using a raw material owned by the people of Ontario. Industries should cooperate because it is reasonable to do so, not because the Ministry says they must. Companies should be prepared to work together to improve overall utilization, not merely because they will increase their profits but because it is good forest management.

Birch (*Betula* spp.) is not utilized to any extent at the present time, although there has been an increase in recent years in the amount of birch picked up from cutovers for fuelwood. This will not have a major impact on most of our cutovers because large volumes are available and cutovers are far from communities.

The deciduous content left on many cutovers creates problems as far as subsequent silvicultural treatments are concerned, because such cutovers are difficult to treat and the cost is generally prohibitive. Productive lands are in effect lying idle for what could be a significant portion of the rotation. It will be interesting to see the documented impact of this situation on allowable cuts under the new forest management agreements. I believe we are all in for a big surprise.

The third aspect of utilization that I wish to consider is of an entirely different nature. It is in fact a form of over-utilization. I refer to the present practice of harvesting contiguous annual cuts where working group and age class make this practicable. Often the contiguous cuts are broken up only because of inadequate utilization. The hardwoods and the small conifers of the mature stands are often all that remain standing unless nature provides a break in the age classes.

There are many opinions about the efficacy of this practice. Certainly the short-term economics of harvesting will be good. Concentration of silvicultural effort may be efficient, but what about overall forest management?

Whether we like it or not the forest has values and uses other than those related to wood fibre. However, it is difficult to place a price tag on these items. Hence the forest manager finds it hard to set priorities when different uses dictate a change in normal harvesting patterns or practices. I myself do not believe that large clearcuts are a good forest management technique. The extent of these cuts is primarily a result of the natural concentration of age classes and of the fact that concentrated operations are considered cheaper, at least in the short run. I doubt if long-term economics are considered very often.

One consequence of the general practice of clearcutting large areas is that the second-rotation cut must be similar in size and on the same site because that is where the age classes will be. (I am assuming, of course, that cut areas are regenerated following cutting.) Good forest management requires long-term planning, i.e., planning for the second cut as well as the first. Only in this way can we hope to influence what takes place in the future.

OMNR's Environmental Impact Assessment of forest management practices is based on the premise that all actions from inventory to cut to regeneration to tending and to cutting again are regulated by approved forest management plans which incorporate provisions for the protection of the environment. Such protection extends not only to the natural elements but also to social and aesthetic values. We are in for a rude awakening if we think we can use the plans now available as models for good forest management practices in Ontario. We have talked about forest management for the past 30 years, and we can cite some examples of sincere efforts to implement good management practices, but, by and large, our management plans to date have been strictly short-term logging plans. Furthermore, these are seldom of much use because the data base has proved inadequate as a tool for decision making. Plans can be flexible, but each must be designed to ensure that good forest management remains its primary goal.

What has good management to do with utilization in the boreal mixedwood forest? I believe that until we learn to plan for good forest management and until we are able to predict with reasonable certainty the long-term impacts of our current forestry practices there will be no serious, concerted effort to improve utilization in the mixedwood portion or any other portion of the boreal forest. Our management plans must identify major problems even if we do not yet have solutions to them, because until problems are identified, there is no impetus to seek solutions. We just go our merry way assuming that everything is as it should be.

It is time we realized that the days of unlimited resources are over in Canada. We must not follow the historic pattern of eliminating nature's forest and then undertaking the laborious task of replacing it, as many other countries have done. Surely we can learn this much from history!

UTILIZATION OF UNDERUTILIZED SPECIES IN THE BOREAL MIXEDWOOD FOREST IN ONTARIO

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and

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Underutilized hardwood species (poplar [Populus *spp.*] *and white birch* [Betula papyrifera *Marsh.*]) *will be the raw material of the future because Canada's forest industry is facing supply constraints on coniferous species and an increasing demand for fibre. Hardwoods are abundant and could be used by integrated industrial complexes producing high value-added products and achieving full utilization of the hardwood fibres. Lumber, composite lumber, panelboard products, energy, chemicals and food are some of the options described for which, in most cases, processing technology needs either to be transferred or demonstrated.*

Les feuillus sous-exploités comme le Peuplier (Populus *spp.*) *et le Bouleau à papier* (Betula papyrifera *Marsh.*) *seront les matières premières de l'avenir, étant donné que l'industrie forestière du Canada fait face à des difficultés d'approvisionnement en conifères et à un accroissement de la demande de fibres. Les feuillus abondent et pourraient être exploités par des complexes industriels intégrés fabriquant des produits à forte valeur ajoutée et utilisant toutes les fibres de bois feuillu. Le bois d'oeuvre, le bois composite, le carton pour panneaux, l'énergie, les produits chimiques et les aliments constituent certaines des possibilités décrites, pour lesquelles, dans la plupart des cas, la technique de fabrication doit être adaptée ou éprouvée.*

The forest industry's heavy reliance on coniferous species may have to be reduced in the future because the rate of coniferous regeneration will be inadequate to meet the demand for fibre. If increasing transportation costs are considered, we may have reached that critical stage already. Hardwoods, especially underutilized species such as poplar (*Populus* spp.) and birch (*Betula* spp.) represent the major opportunity for expansion of the industry. As an alternative to increasing the supply of conifers, the industry could be encouraged to utilize more hardwoods.

Projections for the next 20 years indicate that domestic and export markets will grow for almost every wood product. The sharpest increase will be in the panel board industry. The American market should remain strong and overseas markets should become more and more accessible to eastern Canada. However, demand will change as traditional products become more difficult to obtain and new products come on the market. Residues and species not used at the present time will go into these products.

Hardwoods are abundant today, and will be the raw material of the future. In Canada, only 5% of the total annual harvest consists of hardwoods, although these comprise more than 20% of the merchantable timber volume. In Ontario, 49% of the province's 1,010.8 million m^3 wood volume of hardwoods is poplar. This species alone represents 18% of the total productive wood volume of all species in Ontario. Approximately 11% of the annual allowable cut is used in four major industries: of this 11%, approximately 35% goes to pulp and paper, 30% to plywood, 30% to panel board, and 5% to sawmilling industries. White birch (*Betula papyrifera* Marsh.) accounts for 30% of all Ontario hardwoods. In 1978, 66,000 m^3 of white birch was harvested.

There are several reasons for the relatively low consumption of these species: lack of economic incentive because preferred softwoods were abundantly available, inaccessibility of many large stands, overmaturity of stands with a consequent high incidence of decay, small diameter trees, low market demand. Today, however, forest managers are much more anxious to use these "weed" species. They face a shortage of softwoods and would like to remove offsite hardwood stands for conversion to softwoods. They would like to improve the growth and quality of trees, but before they can do this, they must harvest the present stands. Until poplar and white birch are used by the industry on a large scale, however, intensive harvesting will not be undertaken.

These hardwoods have tremendous potential. They can be substituted for softwoods in most cases, and can serve as the raw material for many new wood-based products. Virtually 100% of their fibrous components can be utilized. In fact, they could become the universal material of the future.

The best way to utilize the poplar and white birch resource would appear to be through the development of integrated industrial complexes. The objective would be to develop as many high value-added products as possible. An optimum multi-product complex might consist of a plywood plant, a waferboard mill, a sawmill, a mill using waste (chemical, food or energy plant) and a secondary wood manufacturing plant (pallet, container, core stock, furniture, log cabins, furniture framing, wood turning, excelsior, paneling, canoe paddles, etc.). Such complexes would lead to full utilization of raw materials from the forest. Industrial integration in the softwood conversion mills would also lead to full utilization.

In many cases, the processing technology is already known and needs only to be transferred to the appropriate potential user. Other products and processes require additional development work, but a demonstration phase could be undertaken on short notice. Some opportunities are still at the research or conceptual stage.

Let us now examine briefly what could be done.

Lumber and Composite Lumber

Conventional harvesting techniques do not allow the extraction of all high-value growth. Short-log cutting and milling systems (2 m or less), capable of processing several species and producing a wide range of products, should be implemented. In addition to yielding high-value lumber for furniture components from small and crooked trees, low-grade categories could be used for pallet stock, new types of decorative panelling, blockboard and other products.

The use of these hardwoods as structural timbers has not yet been fully studied in Canada. The building codes accept poplar and birch already. Lumber from some hardwoods is less resistant to fungi. It may be weaker and less stable dimensionally than some of the species used for construction lumber, but it can be used for many purposes, especially wall studs and other compression members, and service requirements for these can be met easily.

At the present time, large quantities of trees are available for processing with modern veneer lathes. While some of the poplars are suitable for plywood, the ability of the domestic and export markets to absorb enormous volumes of this product is limited. There is great potential for the production of laminated veneer lumber. This is a high-quality, high-strength lumber product that is produced in a continuous process, the so-called Micro-Lam process, with variable lengths. Laminated lumber is used for roof and floor trusses and for a wide variety of engineered structural products. The process is not limited to veneer of any specific length, so that veneer cut from shorter logs can also be used.

There are other types of composite lumber which could be manufactured as well, e.g., Press-Lam (vertically laid thick veneer) and Com-ply lumber (particleboard core with veneer overlay). Composite lumber can also be made from particleboard or waferboard laminated with glue, nails, or double-toothed metal plate. If hardwood raw material were used, the products would have to be examined carefully, because, until now, they have been made from softwood species. To produce long, high-strength composite lumber from short pieces, edge and end gluing techniques, such as those used in the EGAR system (edge glue and rip) or the structural end finger jointing system could be employed.

At Forintek, we have conceived a new system of manufacturing composite lumber using a variety of innovations that we have developed (Figure 1). This concept, which was originally designed to utilize small, fast-growing hybrid poplar, could be easily adapted to the natural hardwoods or even softwoods. For example, in the case of a 5-year-old piece of wood, eight uniform slats 13 mm thick x 40 cm wide and one metre or more in length can be obtained by slicing. When these pieces are assembled using conventional butt and edge gluing techniques, lumber of any dimension which is strong and attractive can be produced. The material handling techniques would be similar to those employed in Europe for the production of blockboard. This composite material has a similar density to that of trees in the spruce (*Picea* spp.)-pine (*Pinus* spp.)-fir (*Abies* spp.) group but has a higher modulus of rupture and lower variability, and is comparable in stiffness with the wood of southern yellow pines.

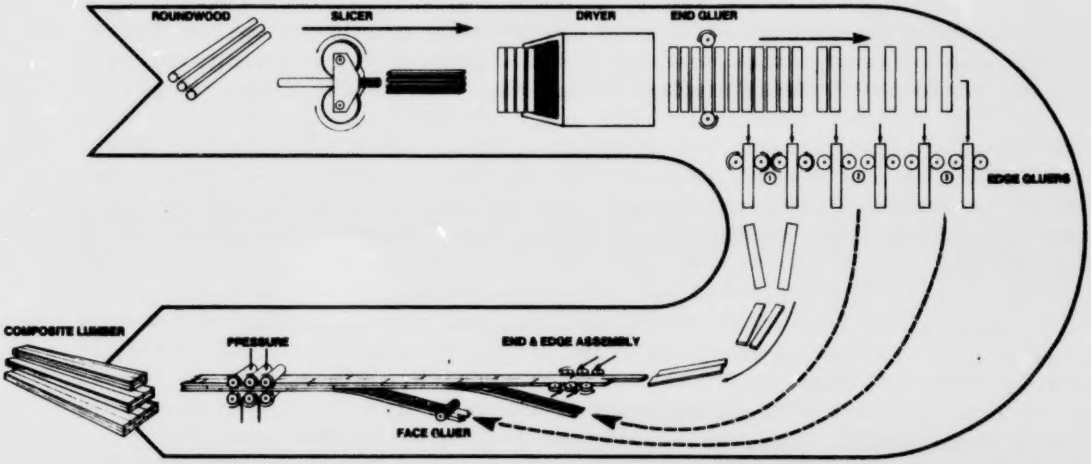

Figure 1. Process for the manufacture of poplar composite lumber.

Panelboard Products

The waferboard industry is expanding rapidly. At the present time, it is based principally on poplar. However, mixed species could be harvested together and combined in the manufacture of waferboards, harvesting operations could thereby be simplified, and mixed forest stands could be utilized more fully.

Medium-density panels could be manufactured from the waste of high-quality hardwoods and from low-quality trees. Such reconstituted wood is being used to a greater degree as the furniture industry expands. Because Canada does not yet have any mills for producing panels of this type, there is enormous potential for a new industry. In view of the gluing techniques that are being developed to lower costs, medium-density panels could be produced in Canada for export.

The objective here will always be the total use of all the woody material (wood, bark, leaves) in a single process. Our preliminary research leads us to believe that it would be possible to manufacture a panel of 100% wood without the addition of any adhesive. This would be a new product consuming an appreciable volume of material that is wasted at the present time.

Energy

The generation of energy from forest biomass is a recognized priority of the federal government. Energy can be obtained from forest biomass either by direct combustion or by the production of liquid fuels, but whichever method is employed, the use of forest biomass for energy should be included in forest management plans.

Gasification of forest biomass provides an excellent option for the production of energy and chemicals from wood. This technology is undergoing rapid development in Canada and has been demonstrated on a pilot scale by several companies. The gas produced has a low energy value (100 to 150 BTU per standard dry ft^3) (890-1335 kg cal. per standard dry m^3) and may be burned directly to provide energy. However, the processes developed to date using forest biomass are not economically practicable, in comparison with those using fossil fuels, for large-scale power generation.

Competing applications for materials, and the high cost of handling and transportation involved in supplying the wood from a relatively large area (800 to 1,600 square km for a 150 megawatt plant) are the major economic factors mitigating against the development of gasification on a large scale. However, continued increases in the cost of fossil fuels, dwindling supplies of these fuels, and trends toward short-term, high-yield forest plantations are certainly changing the economic picture. Even now, small gasification units could compete favorably with high-priced conventional fuels in remote northern communities. The gas produced could be used conveniently as fuel in local industries and homes.

Further advances in the application of gasification technology to forest biomass will necessitate a fundamental understanding of the complex chemical reactions which occur during gasification, including reaction kinetics, thermodynamics and catalytic effects. This knowledge can then be applied to the manipulation of the reaction conditions in order to produce the gas more efficiently at compositions and at molecular ratios suitable for conversion to a wide variety of chemicals including methanol. Methanol may be used as a liquid fuel or converted to gasoline.

The conversion of wood to sugars and hence to alcohol (ethanol and others) and to chemical products is another avenue for energy generation and the conservation of fossil energy. The techniques of biotransformation are less damaging to the environment than other methods of producing energy and seem to give the best results. At present, there are two major problems: pre-treatment of biomass and reduction of the cost of enzymes.

Chemicals

The steady increase in the price of petrochemicals is a stimulant for the transformation of wood material to chemical products. The production of phenol for synthetic resins, for example, is only a small portion of the petrochemical industry. As fuel supplies dwindle, the resins could become very scarce and their price would increase even faster than that of crude oil. In fact, this is already happening. Even now, glues represent more than half the price of panels.

Nearly 30% of wood consists of lignin, a natural glue. Forintek has already manufactured adhesives from wood lignin derived from pulp mill waste liquor. The market for adhesives for use in panel products alone has increased to about 26,100 tonnes. The potential of these lignin-based adhesives is not limited to use in wood products. They could also be used in insulating products, in the foundry industry, as a glue for molding, etc. Therefore, it makes sense to try these cheap lignin resins as replacements for all thermosetting resins.

Lignin and other wood-based chemicals have other uses as well. Moreover, lignin can be obtained from sources other than pulp mills. A special steam treatment permits the separation of wood into its three fundamental constituents: cellulose, hemicellulose and lignin. From cellulose we can obtain glucose, ethanol, esters and ether. From lignin we can produce phenol, benzene cresols and other phenolic compounds. From hardwoods we can extract hemicellulose, xylose, acetone and butane. With all these chemical products, it is possible to make thermoplastic resins (styrene), thermohardening resins (epoxy, polyester, phenolics), synthetic fibers (nylon) and synthetic rubber.

Over the long term, wood is a viable option as a raw material because it is a renewable resource. It can be produced in vast quantities in intensively managed, genetically improved forests and it is environmentally safe.

Deriving chemicals from wood is not new. The destructive distillation of wood has been practised since ancient times to produce charcoal. More recently the controlled thermal degradation of wood by pyrolysis and distillation provided a source of chemicals. These processes became uneconomical and inconvenient as coal, petroleum and natural gas became widely available.

Nevertheless, vast quantities of chemicals are still being produced from wood through the traditional pulping processes. These processes emphasize the production of cellulose for the manufacture of paper and paper products to the detriment of the other polymers which, for the most part, are disposed of as wastes or burnt for energy. Other chemicals produced by the pulping process include cellulose esters, cellulose ethers and rayons which are used in the textile industry; wood resins, turpentine, pine oil, tall oil, tall oil fatty acids, dimethylsulfide and dimethyl sulfoxide which are used as chemical solvents and chemical intermediates; kraft lignin and lignin sulfonates which may be used in dispersants, binders, coagulants, polymer additives, pharmaceuticals, phenols, and as a source of energy; and miscellaneous chemicals including furfural, vanallin, yeasts, hemicellulose extracts, etc.

More sophisticated wood refining processes are envisioned for the future in which wood will be treated as a feedstock much as crude oil is today. Such processes are less severe than the current pulping processes and will lead to the recovery of the three basic wood polymers in forms which are more readily convertible into a wide variety of chemicals.

Food

The world is speeding toward a food shortage. In many places around the globe people are starving already. It is known that wood cellulose is a potential source of energy for ruminants. Untreated, it is almost unassimilable because of lignin. Once this has been removed, the cellulose is perfectly digestible. Conventional techniques (pulp manufacture) are too expensive for this purpose. Through the use of a simple, economical steam treatment, poplar can be treated efficiently. The forage wood could be provided by the cellulose and the lignin could be used in the fabrication of chemical products as already described.

Conclusion

There are numerous other items which can be produced from hardwoods, such as composite poles, composite railway ties, laminated ties, preserved hardwood products, etc. Nevertheless, simply on the basis of what we have outlined in this brief paper, we think you will agree with us that our hardwood species are underutilized at the present time. Increasing the utilization of hardwood material is a promising means of augmenting timber supplies in the future. By developing and adopting new technology we will be better able to meet the increased demand for wood in the future.

SUGGESTED READING

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Clarke, M.R. 1980. The development of high value structural products from poplar. Forintek Canada Corp., Eastern For. Prod. Lab., Ottawa, Ont.

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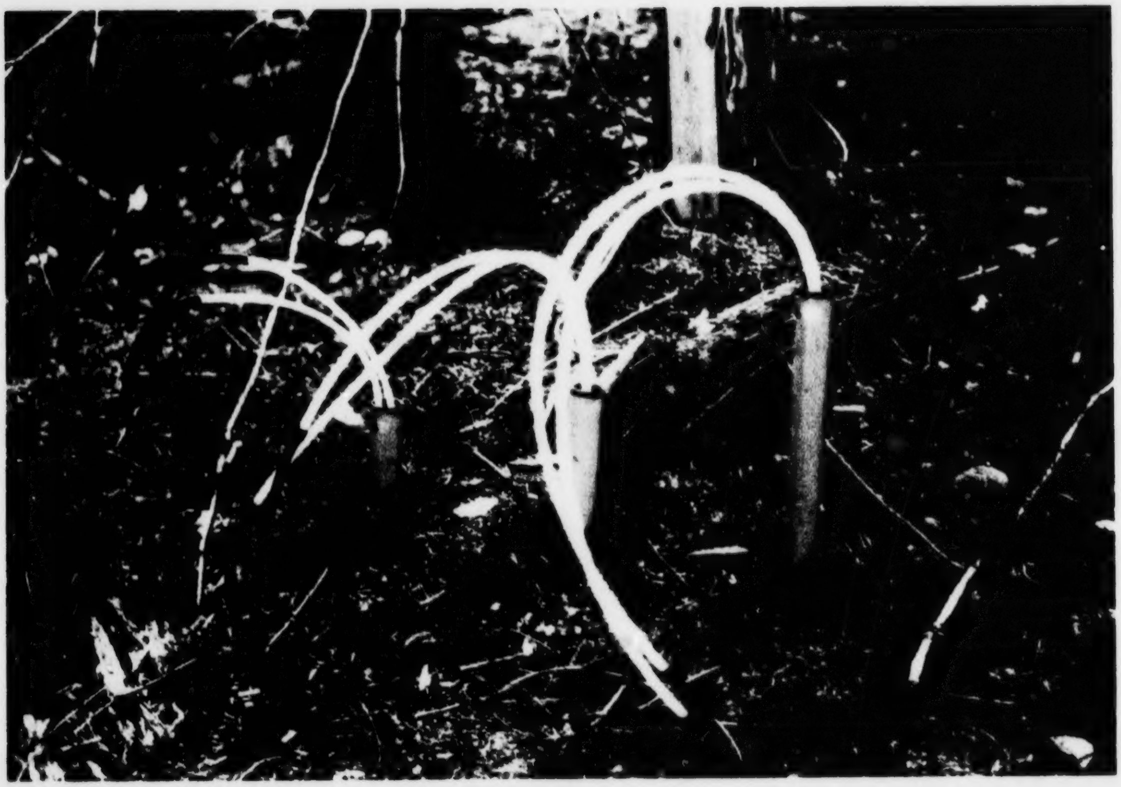
Discussion

No discussion was recorded for Session III.

SESSION IV: IMPACTS OF HARVESTING THE BOREAL MIXEDWOOD FOREST



Sampling of soil solution to determine nutrient concentrations following harvesting in mixedwood forest.

SESSION IV: IMPACTS OF HARVESTING THE BOREAL MIXEDWOOD FOREST

Introduction (*R.A. Haig*)

All previous papers have emphasized the complexity of the boreal mixedwood forest, and the difficult technical problems this presents. The papers in this session suggest that the technical problems may be easier to solve than those relating to the conflicting objectives of various agencies, organizations, and interest groups.

As noted in Session III, underutilization of hardwoods and balsam fir is seen by the forester as a major impediment to management of the boreal mixedwoods (i.e., for fibre). It prevents effective regeneration to the more desirable spruces, and hence it perpetuates a situation in which the area is producing far less than its potential in merchantable fibre. To maximize yield it would be desirable to remove the hardwoods and balsam fir along with the spruce, thereby facilitating site preparation and establishment of a new stand containing a high proportion of spruce. However, Messrs. McNicol and Timmerman, as wildlife managers interested in maximizing the ungulate population, appear to favor the conventional logging practice which removes only the mature conifers, leaving mature hardwoods, a diverse deciduous browse component, and sufficient conifers to provide cover. If markets improve for hardwoods and balsam fir, and if foresters develop cost-effective methods of regenerating well stocked stands of spruce on mixedwood sites, the quality of the habitat for ungulates (and for many other species as well) can be expected to decrease in proportion to the degree to which the objective of maximum merchantable fibre is attained. In other words, the objectives of foresters and wildlife managers appear to be directly opposed. Furthermore, as an ornithologist, Dr. Welsh notes that even harvesting of the mature conifers will affect the suitability of the habitat for some species of birds, and the implication is that even a partially cut area will not support as broad a range of species as the uncut mixedwood forest. Finally, as an ecologist, Dr. Gordon questions whether the long-term productivity of the sites can be maintained if we reach the stage where total biomass is being harvested on short rotations.

Recognizing that we must eventually make some compromises to meet a range of objectives, I think it is most important at this stage that as forest managers we demonstrate that we can solve the technical problem of managing the boreal mixedwood for maximum merchantable fibre yield. While we are doing this we (and our colleagues in other disciplines) should also be measuring the effect this has on the other "products" of the boreal forest and on site productivity itself (ungulates, birds, etc.). When we have the necessary information to develop valid cost-benefit ratios, we can then begin to make rational decisions regarding allocation of land and resources for various purposes.

However, I should let you hear the speakers, so that you can judge for yourselves how difficult the problem of conflicting objectives may be.

IMPACTS OF HARVESTING ON NUTRIENT CYCLING IN THE BOREAL MIXEDWOOD FOREST

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Biomass, productivity and nutrient cycling are demonstrated for typical boreal mixedwoods and the consequences of full-tree logging and biomass harvesting are considered. Data for other boreal stands such as black spruce indicate that dry outwash sand plains and organic soils may not sustain full-tree logging. In contrast, the budgets, while liberal, of average boreal mixedwoods indicate that full-tree logging can probably be sustained. This is more likely if slash is left. Phosphorus, however, may still become limiting. The consequences of site preparation methods are discussed.

La biomasse, la productivité et le cycle des éléments nutritifs des forêts boréales mélangées typiques sont décrits et les conséquences de l'exploitation par arbres entiers et de la récolte de la biomasse sont considérés. Il appert des données disponibles pour d'autres peuplements boréaux, comme ceux d'Épinette noire, que les plaines fluvio-glaciaires de sable sec et les sols organiques pourraient ne pas se prêter à l'exploitation par arbres entiers. Par contre, les bilans des forêts boréales mélangées moyennes, tant qu'ils sont généreux, montrent que celles-ci pourraient s'y prêter, ce qui est encore plus probable si les rémanents sont laissés sur place. Mais le phosphore pourrait devenir un facteur limitatif. Les effets des méthodes de préparation des stations sont discutés.

Recent interest in forests as a source of energy has spawned an array of short-term studies, many of which are seeking 'clear-cut' answers to the simple question: "Can we or can't we utilize whole organic stocks (biomass harvesting) from forests for energy or fibre?" The practices of clearcutting and conventional logging vs full-tree or whole-tree logging are variations of the same theme. In this paper, full-tree logging refers to the removal of all aboveground portions of trees. Whole-tree logging refers to all aboveground and belowground parts of the tree.

Stability of an ecosystem may be loosely defined as the integrity of its composition and productivity. To maintain stability following massive disturbance, it is necessary for an ecosystem to have resistance or resilience. Resistance is the ability to remain unchanged by disturbance, as, for example, in a budworm attack. Resilience is the ability to return to the original state following disturbance. This is what we might hope for with respect to some silvicultural practices. Resilience, in terms of the nutrient cycle, means sufficient site capital and atmospheric inputs to sustain the demands of a developing young stand whose nutrient demand is high, through crown closure and eventually to steady state where input equals output. At this point nutrient cycling within the stand is considered maximal.

The processes involving transfer and transformation of organic matter and those of nutrient dynamics are complex: nutrient transformations such as decomposition and, for example, in the case of nitrogen, mineralization (the decomposition of nitrogen-containing organic compounds resulting in the release of ammonium or ammonia); nitrification (the microbial oxidation of ammonium to nitrite and nitrate); denitrification; uptake; internal and external cycling; transport through the soil; leaching and weathering; immobilization by decomposers, by the shifting of cation-anion balances, by clay lattice fixation, by adsorption and by chelation; the regulation of redox potential which may affect the solubilities of some nutrients as conditions change from oxidizing to reducing systems or back again. These processes are all affected by temporal considerations: e.g., the seasonal dynamics, the successional stage of the stand and so on.

In addition to the foregoing complexities, there are difficulties in measuring rates of weathering for many of the harder rocks and minerals, and difficulties in measuring leachates in some soils, particularly those which are in snowmelt soil-charging systems for substantial parts of the year. There are particular difficulties in measuring and interpreting some elements such as soil phosphorus. The measurement of available supplies of potassium is easy. Its interpretation is more difficult. Its replacement begins relatively quickly through soil chemical processes in some soils but not in others (Stone 1979). Massive potassium deficiency for tree growth can be readily demonstrated in soils that may have considerable (but as yet unavailable) potassium supplies (Heiburg et al. 1959, Leaf et al. 1975). Similarly, magnesium is generally present in substantial amounts in forest soils, yet deficiency in red pine (*Pinus resinosa* Ait.) (Stone 1953) has also been demonstrated. Carlisle and Methven (1975) in an excellent review paper caution that soil fertility estimates often depend upon variable sampling depths, analytical problems of measuring nutrient totals and availability, and whether or not unavailable nutrients (such as those as yet unweathered in deep parts of the profile or in certain rocks) are legitimately included. Despite these difficulties, we can structure ecosystems and compartmentalize the cycles. As more information becomes available, refinements can proceed in the problem compartments.

I have not attempted to order the foregoing list, nor for that matter to exhaust the list of processes. There are many others. One point I would like to make apart from the nature of the complexities is this: it is scarcely possible to affect one component or process of an ecosystem without affecting most or all of the others.

To indicate the practical significance of the consequences of these processes, Mälkönen (1979) points out that in northern forests the importance of nitrogen in logging residue as compared to that in the humus layer is considerable. Its availability is greater because it decomposes more rapidly in the slash than in the humus. Likens et al. (1978) have shown that nitrogen inputs from precipitation alone would take 100 years to replace losses following clearcutting in northern tolerant hardwoods, but accumulation from gaseous exchange would reduce replacement time to only 20 years. The source of gaseous nitrogen is microbial fixation in dead wood, e.g., the slash remaining after clearcutting.

To return again to the question of "can we or can't we" and to indicate the range of possibilities, let us look at a few examples. Stark (1979) claimed that soil reserve nutrients were sufficient to sustain 70- to 100-year rotations of conventional logging of alpine larch (*Larix lyallii* Parl.) and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) for 28,000 to 40,000 years before most ions would be depleted. It would take up to 8,000 years for phosphorus depletion. This site, however, though somewhat dry, was a rich juvenile soil of argillite, limestone and partly volcanic origin. The reserve calculations included the total profile and also the weatherable rocks.

For whole-tree harvesting in the leafless period, Boyle and Ek (1972) provide an example of soil reserve nutrients alone exceeding nutrient removal in fertile aspen (*Populus* spp.) and mixed-hardwood soils in Wisconsin, sufficient at least to support two 45-year rotations.

Nykvist (1974) indicated that, for spruce (*Picea* spp.) stands in Sweden, nutrient losses through leaching and whole-tree harvesting did not exceed atmospheric inputs. Kimmins (1977), however, noted that it was not quite so simple, as there was not an increase in nutrient levels on infertile sites commensurate with time. This in turn indicated that only a fraction of these inputs was being retained in such systems.

Kimmins and Krumlik (1976) showed that the removal of nutrients through full-tree harvesting was substantial in comparison with the quantities remaining in soil reserves in spruce-fir (*Abies* spp.) and other conifer stands. Particularly critical was the depletion of calcium and potassium. Nitrogen was also severely depleted.

Gordon (1979) showed that in full-tree harvesting of red spruce (*P. rubens* Sarg.) stands, replacement times were moderate for nitrogen and magnesium, but on better sites phosphorus could take up to 50 years and potassium 80 years to replace. In black spruce (*P. mariana* [Mill.] B.S.P.) stands, replacement times for potassium were up to 56 years.

Kreutzer and Reemtsma (1979) showed that in German spruce and pine (*Pinus* spp.) stands from contrasting site classes, the nutrient export due to full-tree logging is relatively higher on low-yield sites. On high-yield sites the absolute amounts exported are higher. Calcium and potassium are generally problem nutrients.

The compounding effects of shortened rotations have been examined by White (1974) who found that, even on good cottonwood soils in the south, nitrogen, phosphorus and potassium would all become limiting. Pritchett and Smith (1974), from fertilized plantation experiments in United States coastal plain soils, indicated that there was insufficient phosphorus to sustain 20-year rotations of slash pine (*Pinus elliottii* Engelm. var. *elliottii*).

Both Malkonen (1979) and Tamm (1979) caution that an understanding of the effects of intensive harvesting requires a sound ecological basis. Tamm (ibid.) points out that the technology for remedial measures such as fertilizing is available. In fact, in some forests in Sweden, these measures are already in place. However, Tamm also notes that intensive harvesting, particularly when combined with short rotations, is a new circumstance and the previous examples of intensive use of all forest products in Europe are not reassuring. Mälkönen (1979) indicates that maintaining wood production even at its former level may require soil amelioration measures beyond our capacity.

What, then, are the chances of stability in the upland mixedwood of the boreal forest under a full-tree harvesting system?

The boreal mixedwood cover type is described under types 9 and 36 (SAF 1954). Landscapes with which the type is associated vary from undulating till plains with a moderate amount of stone to upland argillaceous sands and clay plains. The soils may be clay with a high or low lime content, clay over rock knobs or clay over gravel, silt with a low lime content, loam with a low or moderate lime content, siliceous or limey fine sand over rock knobs (Hills 1954). Topographically the type extends from upper and midslope positions on moderately sloping terrain to (occasionally) lower slope positions. Moisture regimes vary commonly from fresh to moist. Stand composition varies repeatedly and endlessly from predominantly aspen to predominantly white spruce (*Picea glauca* [Moench] Voss) and balsam fir (*Abies balsamea* [L.] Mill.). White birch (*Betula papyrifera* Marsh.) is common on the stonier profile variants. The strongly controlling influence of climate on the distribution of the type in the boreal forest is evident when the wide array of upland sites it occupies is considered. The consequent array of nutrient regimes available to it is important in the nutrient cycle.

We selected some plots in the mixedwood type in the Black River watershed of the Terrace Bay District and the Blackwater River watershed of the Nipigon District. They are not particularly good stands, just average mixedwood. Basal area averages 2.3 m^2 ha^{-1}.

There are few data on the mixedwood type. We used extracted samples of our own data for white spruce, with smaller data samples for balsam fir, trembling aspen (*Populus tremuloides* Michx.) and white birch. These latter data were augmented by comparisons and modification of data from elsewhere: for balsam fir (Baskerville 1965, Honer and Heger 1971), white birch (Van Cleve and Noonan 1975, Troth et al. 1976, Jokela et al. 1979), and trembling aspen (Bray and Dudkiewicz 1963, Gorham and Bray 1964, Peterson et al. 1970, Pollard 1971, 1972, Van Cleve and Noonan 1975, Johnston and Bartos 1977, Alban et al. 1978). When examined in detail for characteristic ratios of component distribution, litterfall, etc., these data proved very reasonable. The analytical data dealing with component chemistry, ground flora, soils, precipitation chemistry, etc., are our own.

Aboveground Biomass and Reserves

In Figure 1 biomass and reserves of an upland mixedwood with two black spruce stands are compared. For simplification, data on flowers and fruit are combined with data on foliage, and data on bark are combined with data on bole weight. 'Standing dead' is included here as a fraction of soil reserves. Data on roots and lesser vegetation including shrubs are omitted here but are incorporated in other calculations to be explained later. Mineral soil reserves are calculated from depth of deepest rooting. It should be pointed out that these data are from actual stands and are unadjusted for comparison. As indicated earlier, the mixedwood stand is a mediocre one. Had more time been available, stands with better site occupancy could have been located in which greater biomass accumulation would have been apparent. It would normally be expected that the standing crop biomass on the upland mixedwood would be greater than that on either of the black spruce sites at steady state. It should also be noted that weights of shrubs and lesser vegetation, which are much greater on the mixedwood site and much less important on the black spruce sites, are not included in this diagram because of arguments restricting full-tree harvesting to trees. For these reasons, direct comparisons with the standing crop of black spruce stands should be avoided.

Similarly, the black spruce stands are not directly comparable because they are of different ages. The stand on the outwash sand is approximately 50 years old, about half the age of the stand on the peat. The latter has greater biomass accumulation at the present time. That on the outwash will obviously have substantially more when it reaches the same age. The cycling of all three stands may be compared generally, however, since the crowns are closed and the stands well developed. They are in steady state.

A number of points should be noted. While the black spruce stands have roughly the same standing crop, and their component weights are proportionate, the branch weight of the mixedwood stand is relatively greater and the foliage weight relatively much less. This effect is related to the proportion of hardwood in the stand and the much lower proportion of white spruce (in this case 25%) than in the black spruce stands which are 100% spruce.

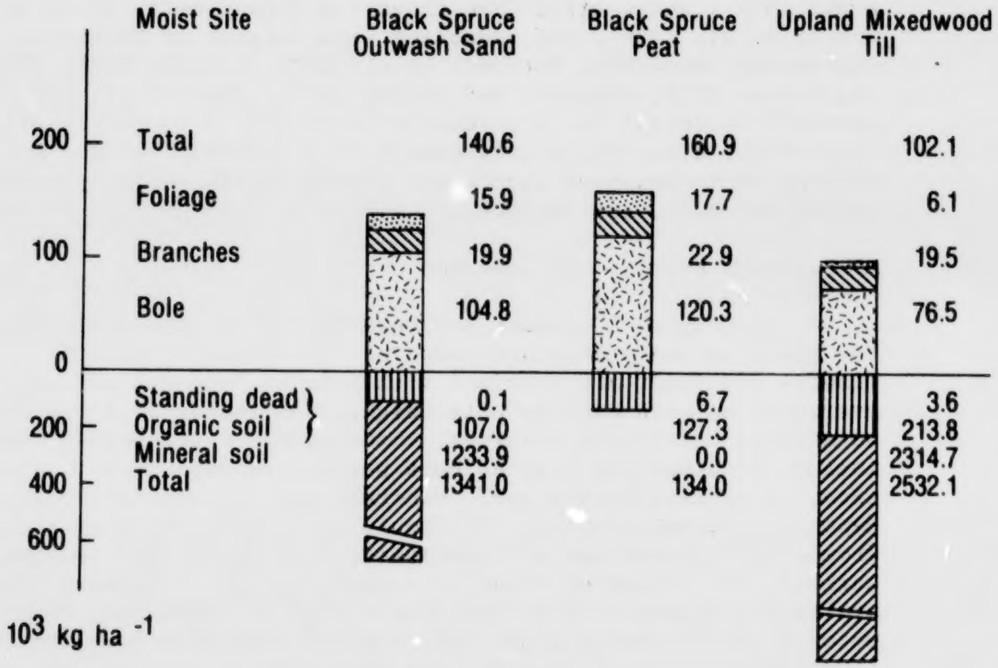

Figure 1. Standing crop dry matter and reserves of different land types supporting spruce and upland mixedwoods.

What is more important, it may be seen in comparing the total standing crop of the black spruce stands on the peat and the outwash that the total available for removal in full-tree harvesting exceeds that of the organic reserves by more than 100%. That is, more than half of the total organic matter pool is in the standing crop of both these black spruce sites. In contrast, it may be seen in the mixedwood site that the total standing crop represents only slightly less than 50% of the organic reserves and only about one third of the total organic pool of this site. Mixedwood stands carrying greater standing crops or with more recent fire history would not enjoy such a liberal ratio.

Stand Composition

Four species contribute to the mixedwood standing crop and do so in different ways. For example, fir crowns consistently weighed less than 60% of spruce crowns. Alban et al. (1978) point out that in Minnesota in adjacent stands of pure species, crown weights (branches and foliage) are much greater for spruce than for aspen, but that bole and bark weights are greatest for aspen. Our data support these findings, although our mediocre mixedwood stand has roughly only half the basal area (20.3 vs 34.7 m^2 ha^{-1}) and standing crop that the Minnesota stands have. The stand histories of these contrasting examples represent the most important difference. Further, the Minnesota stands are north temperate, whereas the Ontario examples are boreal. The climate is much more severe in the latter and the productivity is lower. In contrast to those in the Ontario example, the shrub layer and lesser vegetation of the dense Minnesota stands contribute little to total biomass. Incidentally, Alban et al. (1978) also noted that, were the Minnesota aspen stand to be full-tree logged, the quantity of nutrients removed would be twice as great as in the Wisconsin aspen stand (Boyle and Ek 1972) previously noted in this paper. The latter is a frequently cited paper demonstrating the feasibility of repeated cropping. These authors, however, do not recommend shortened rotations.

Similar comparisons can be made for jack pine (*Pinus banksiana* Lamb.) and spruce (*Picea* spp.) (cf. Gordon 1979). Dobie and McIntosh (1976) showed that spruce foliage weights were triple those of pine and that it took 13 tons (11.7 tonnes) of spruce full-tree dry matter to yield 1 ton (.9 tonnes) of dry commercial foliage. It took 42 tons (37.9 tonnes) of pine for the same yield. This has important consequences when one considers both organic matter and nutrient removals in full-tree logging and shortened rotations.

Because of species differences noted above, Figure 2 is presented to show the variation in composition from 25% softwood (spruce and fir grouped) and 75% hardwood (aspen and white birch grouped) to the converse mixture. These variations in composition are all on the same site. It may be seen that differences are slight. In the predominantly softwood stand, the contribution of foliage weight is twice that of the predominantly hardwood stand, largely an effect of the white spruce foliage component. Conversely, bole weight is slightly greater where hardwoods predominate, a consequence of heavier bole and bark weights of aspen. It should be noted that, were there to be a shift to pure softwoods or hardwoods through silvicultural manipulation, there would be noticeable differences which would have an important effect on organic matter and nutrient removals in full-tree logging.

Productivity

Steady state aboveground productivity is presented in Table 1. Productivity is seen to diminish from predominantly hardwoods to predominantly softwoods. This results from differences in growth characteristics of these species when they are grown in mixtures. These values, while generally low, are actual and demonstrate differences in composition of the sample mixedwood stands. Again, these values should not be used for direct comparisons with other cover types, even at the same latitude, without regard for other parameters, i.e. stocking, age, etc.

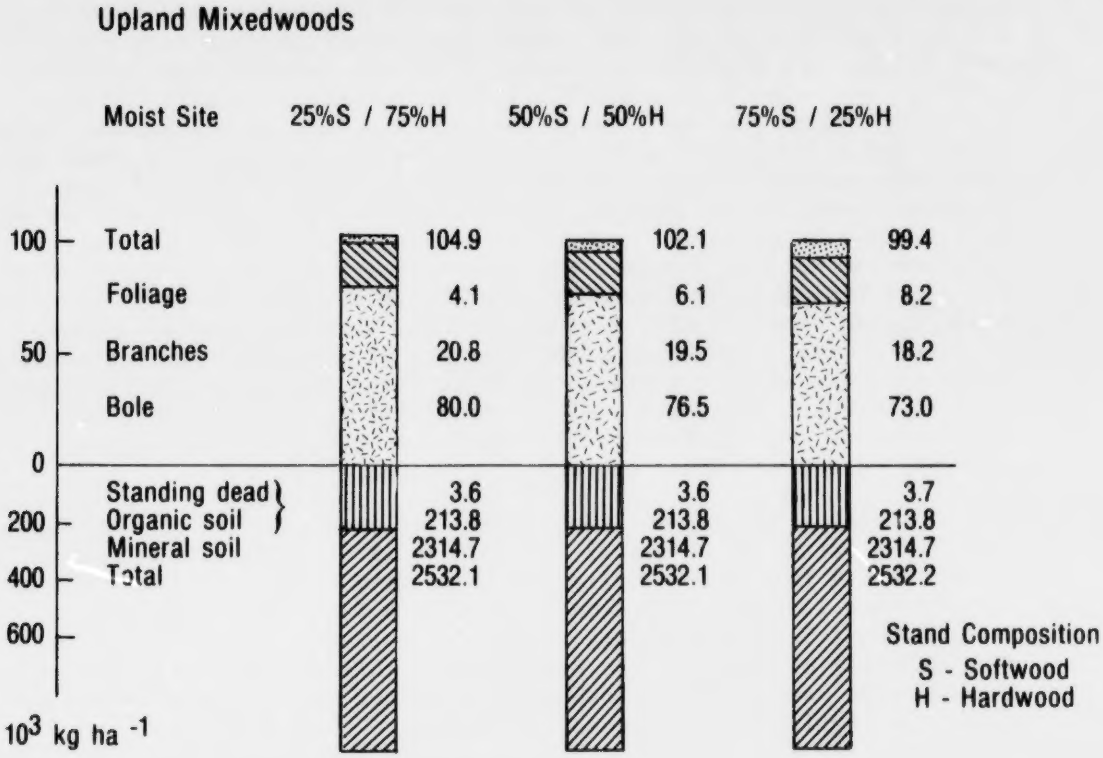

Figure 2. Standing crop dry matter and reserves of upland mixedwoods of varying stand composition.

Table 1. Aboveground productivity (litterfall and increment).

Latitude	Mixedwood				kg ha^{-1}yr^{-1}
49°00'N	25%	softwood	75%	hardwood	5178.7
49°00'N	50%	"	50	"	4742.4
49°00'N	75%	"	25%	"	4305.2

Bioelement Stores

Bioelement stores to a large extent reflect the biomass in the standing crop. In Figure 3, data for five macroelements are presented. The aboveground components are grouped, as are standing dead, organic and mineral components. The aboveground values are generally low for reasons already indicated. Since the purposes of this paper relate to the removal of standing crop only, in full-tree logging, root data for both trees and all lesser vegetation are omitted, as are those for all aboveground shrubs and lesser vegetation. These data are, however, included later in cycling inputs.

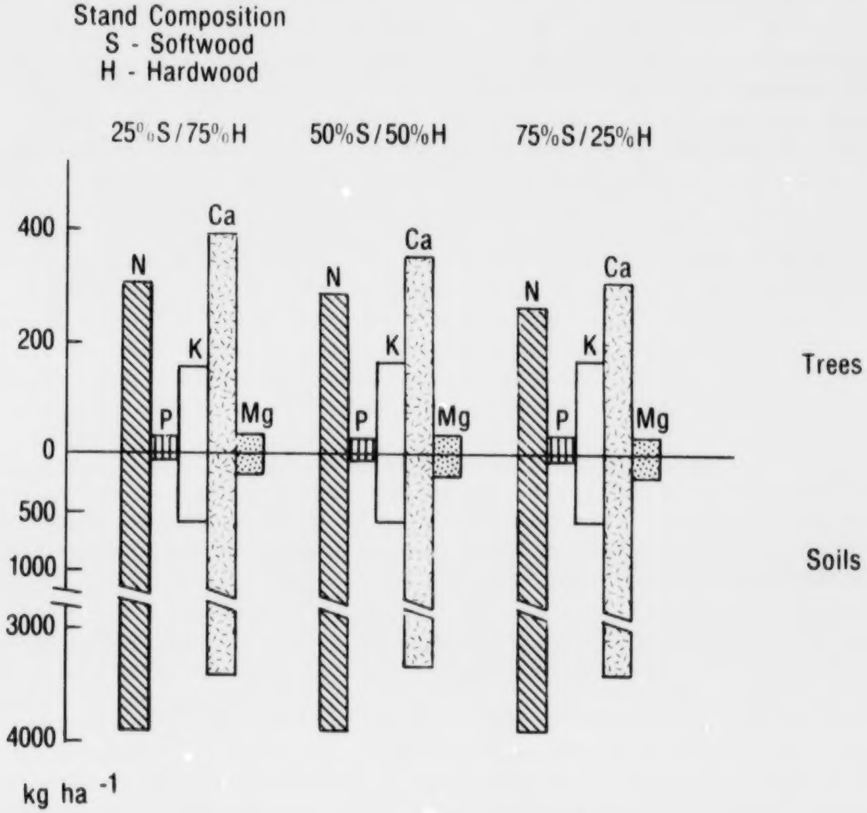

Figure 3. Bioelement stores of upland mixedwoods of varying stand composition.

Only small differences are apparent with respect to stand composition. It may be seen that the amounts of both nitrogen and calcium are less as the softwood component increases relative to hardwood, an effect of higher concentrations of calcium in aspen foliage. This is consistent with the data of Alban et al. (1978) for comparisons of plantations of pure stands of white spruce and aspen. It may be seen that the reserves in the soil are generally adequate to sustain exports represented in this mediocre mixedwood stand. Only in the case of phosphorus is there some indication of insufficiency.

Nutrient Cycling

Figure 4 is a stylized nutrient cycle. Summed values for compartments involving an array of processes are grouped into input, reserves and uptake. Data for roots and subordinate vegetation are included. It is interesting to note that this fairly typical upland mixedwood soil in the boreal forest carries almost ten times more calcium, more than twice as much potassium and almost three times as much magnesium as do granitic soils supporting red spruce in the north temperate forest. Only nitrogen and phosphorus have values that approximate those in these soils (cf. Gordon 1979). Typical outwash soils supporting black spruce in the boreal forest have only one fifth the potassium and magnesium and one tenth the calcium reserves. Phosphorus and nitrogen are about half of those in typical mixedwood site reserves. In input and uptake summary compartments, substantially greater amounts of all nutrients (except nitrogen) are circulating in the boreal mixedwood ecosystem than in the spruce ecosystem on granitic soils in the north temperate forest to the south (ibid.).

Annual input data are presented in Table 2. Slightly increasing values are apparent from the predominantly softwood to the predominantly hardwood stand. This would be due in part to differences in pattern of stemflow between spruce and aspen, and greater subordinate vegetation litterfall under aspen, etc.

Uptake includes the chemical components in tree retention (increment, including roots), litterfall and leafwash (the difference in the amounts of chemical elements entering the system in precipitation and those washed out of the foliage, etc.). Uptake values for the mixedwood ecosystem are presented in Table 3. Small increases in values for all elements from the predominantly softwood to the predominantly hardwood stand probably represent, among other parameters, somewhat faster growth rates in aspen than in spruce, and more rapid breakdown of aspen litter.

Uptake should include estimates of losses in deep leaching. This cycle does not include them. To our knowledge, there are no data on deep percolation on upland mixedwood sites. The effect of this omission is to make the site appear somewhat more conservative, i.e., tighter, than it actually is.

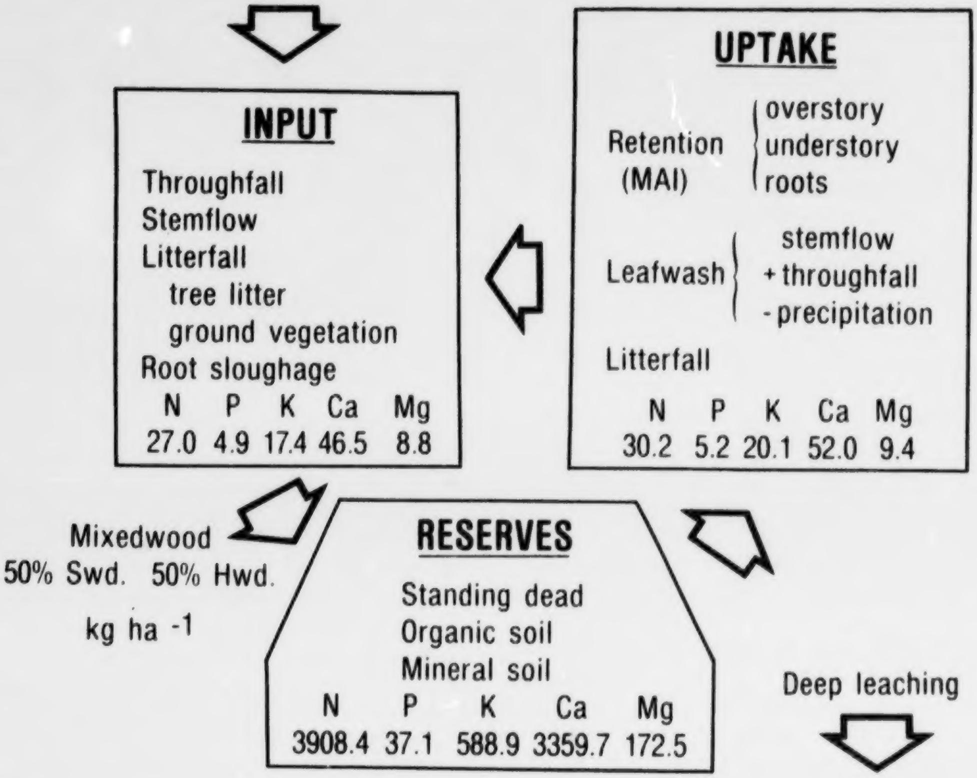
UPTAKE
Retention (MAI)
overstory
understory
roots
Leafwash
stemflow
+ throughfall
- precipitation
Litterfall
N P K Ca Mg
30.2 5.2 20.1 52.0 9.4
INPUT
Throughfall
Stemflow
Litterfall
tree litter
ground vegetation
Root sloughage
N P K Ca Mg
27.0 4.9 17.4 46.5 8.8
Mixedwood
50% Swd. 50% Hwd.
kg ha -1
RESERVES
Standing dead
Organic soil
Mineral soil
N P K Ca Mg
3908.4 37.1 588.9 3359.7 172.5
Deep leaching

Figure 4. Stylized nutrient cycle of upland mixedwoods.

Table 2. Annual input values for mixedwood ecosystem.

	INPUT (Throughfall + stemflow + litterfall + root sloughage)				
	Total N	P	K	Ca	Mg
Mixedwood	(kg $ha^{-1}yr^{-1}$)				
25% softwood 75% hardwood	31.9	6.5	22.2	57.1	11.3
50% " 50% "	27.0	4.9	17.4	46.4	8.8
75% " 25% "	22.5	3.6	13.5	40.0	6.3

Table 3. Annual uptake values for mixedwood ecosystem.

	UPTAKE - Leafwash (TF + SF - P) + litterfall + retention (mai)				
	Total N	P	K	Ca	Mg
Mixedwood	(kg $ha^{-1}yr^{-1}$)				
25% softwood 75% hardwood	35.1	6.8	24.0	63.0	11.6
50% " 50% "	30.2	5.2	20.1	52.0	9.4
75% " 25% "	25.5	4.1	16.5	40.8	6.9

Residence Time

When nutrients enter a system, some remain labile in an immediately available mobile fraction and are taken up by the vegetation or lost by leaching. Others become locked up in other forms in the humus for years. Output may be gradually fed from these sources even in the presence of input from canopy wash. When output equals input, the ecosystem is in steady state.

A good measure of the locking up and release is the residence time. This is the mass of soil organic matter divided by the amount of a nutrient in the input (litterfall, net stemflow and throughfall, etc.). The reciprocal of residence time is the turnover rate ($year^{-1}$) or the fractional turnover. This is the proportion of the nutrient pool involved in the annual flux. Residence time may be considered a constraint on both nutrient availability and loss.

Values for residence time are presented in Table 4. Residence times are seen to be a little longer under predominantly softwood stands than under predominantly hardwood stands. The more rapid breakdown of aspen and birch litter relative to that of spruce and fir is reflected in a more rapid turnover rate. It may be seen that nitrogen is an element some of which may be locked up for long periods, whereas phosphorus, potassium and to some extent magnesium and calcium, have shorter times.

Table 4. Values for residence times.

RESIDENCE TIME - 1/K (Years)

$$K = \text{TURNOVER RATE} = \frac{A}{A+F} = \frac{\text{INPUT}}{\text{INPUT + ORGANIC SOIL}}$$

Mixedwood	Mass	N	P	K	Ca	Mg
25% softwood 75% hardwood	71	84	5	5	15	12
50% softwood 50% hardwood	82	98	6	6	18	16
75% softwood 25% hardwood	85	125	7	8	23	21

Crop Removal: Full-tree Logging

Table 5 presents values for mass and nutrients of the standing crop which would be exported in harvesting as a percentage of the soil reserves. Roots and subordinate vegetation are here considered to be left on the site. Those figures under 100 indicate cases where there is less in the crop than in the soil reserves. As expected, there are no differences in mass with respect to stand composition, but there are some differences in nutrients. For example, it may be seen that harvesting the predominantly hardwood stand will be a little more expensive in calcium loss than harvesting the predominantly softwood stand. It will be recalled that aspen foliage contains greater amounts of calcium than does spruce.

While potassium removal is high relative to that in the organic reserves only, it is reasonably small when organic and mineral reserves are considered together. Phosphorus is probably the only element that may become limiting after harvesting in even this low biomass stand. Its quantity is seen to exceed that in the organic reserves by more than 100%. This means that more than half the phosphorus in the total organic pool is being exported, and almost half in the organic and mineral reserves combined. A stand of greater basal area and biomass would doubtless put even stronger demands on phosphorus reserves.

The mixedwood stands, existing as they do on sites with a moderate component of fines in the soil, have a much better capital in the mineral soil than softwood stands on coarser soils (outwash) containing little or few fines. It should be noted that, in crop removal, the actual reserves in the soil remain on the site and are still available for seedling growth. What is important is the amount of time required to return the organic and nutrient pool to its former level and condition. This is accomplished through atmospheric inputs of nutrients in precipitation and particulate dustfall, as well as mobilization. These nutrients are of course available for leaching and loss, as well as uptake.

Table 5. Nutrient loss in standing crop removal (trees only) as a percentage of reserves.

$$\frac{\text{STANDING CROP (TREES ONLY)}}{\text{RESERVES}} \times 100$$

	ORGANIC RESERVES						ORGANIC AND MINERAL RESERVES					
Mixedwood	Mass	Total N	P	K	Ca	Mg	Mass	Total N	P	K	Ca	Mg
25% softwood 75% hardwood	49	12	142	169	49	33	4	8	94	27	12	24
50% softwood 50% hardwood	48	11	127	176	44	29	4	7	84	28	11	22
75% softwood 25% hardwood	47	10	144	183	38	26	4	7	93	29	9	19

The number of years required for nutrient replacement following full-tree harvesting of a mature stand at full rotation is shown in Table 6. If roots and all organic matter from subordinate vegetation had been included in the harvest as in proposed total biomass harvesting, the replacement times would have been much longer. It may be seen that replacement times for the mixedwood type on these typical soils are relatively short. What this implies is that if full-tree harvesting can proceed without site degradation anywhere in the boreal forest, it will be on these mixedwood sites.

Table 6. An estimate of the number of years required to replace, through input, nutrients lost in a single crop removal.

Mixedwood	Total N	P	K	Ca	Mg
25% softwood 75% hardwood	19	15	17	17	14
50% softwood 50% hardwood	20	16	19	17	14
75% softwood 25% hardwood	21	19	22	18	15

The values presented here are somewhat liberal for a number of reasons. They are calculated on the basis of steady state input (litterfall, net stemflow + throughfall, etc.). It may be recalled that at steady state, internal cycling is maximal, inputs are well utilized and the losses are small. Prior to that, when the stand is young, the demands will be higher. When the stand is old, it becomes leaky. We use steady state since it is a good average over the life of a stand. If we harvest at maturity, we eliminate the leaky stage, and steady state values will no longer apply as an average. These values would have to take into greater account the early stand development period in which input is mainly from precipitation alone.

If we shorten the rotation, the uptake values will be conservative. Nutrient demand will be higher than indicated here while at the same time supplies in the early stages of accumulation will be more limited. Repeated cropping could lead to a gradual emptying of reserves.

A second reason for the relatively rapid replacement times predicted is the low biomass and productivity of this stand in contrast to the good state of its soil reserves. In the present case, this is considered to be attributable to stand history rather than site productivity.

A third consideration is deep leaching. When a stand is harvested, there is a marked increase in nutrient mobilization and release. Maximum losses occur in the first and second years following harvesting (Likens et al. 1978). After regrowth of herbaceous and other pioneer vegetation begins, the site gradually tightens up. Nevertheless, over this period, which may last up to 10 years, losses far exceed the total of annual inputs for many years. Reserves of available forms of nutrients are diminished and replacement times are extended. Surface runoff from melting snow can also substantially diminish the accumulated input loadings (Timmons et al. 1977), even of uncut stands.

There are no on-site deep leaching data for upland mixedwoods. Table 7 provides an estimate of increases in replacement times for nitrogen and calcium from leachate data recorded elsewhere (Likens et al. 1978), and the foregoing cycling and crop removal data. Calcium replacement times increased only slightly, while those for nitrogen increased only by about 10 years.

Thus far, weathering has been omitted from this discussion. Weathering is an extremely important process affecting inputs through time. It depends upon climate, exposure, mineralogy of the parent material, the production of organic acids from the biota, and so on. The products of weathering may enter the nutrient cycle *in situ* through capillary soil action, association with roots, or lattice fixation. They may also be lost to downslope ecosystems by leaching. The mixedwood soils of the boreal forest have a particle size and petrography range which would indicate that inputs should be expected from weathering. Soil climates, however, are generally cool except following disturbance, and rates will be slow. At present there are no weathering data on soils of this type. Excellent discussions of weathering are noted in Gorham et al. (1979) and Clayton (1979).

Table 7. Replacement time in years (crop removal and two-year leachate).

Mixedwood		Total N	Ca
25% softwood	75% hardwood	26	20
50% softwood	50% hardwood	28	21
75% softwood	25% hardwood	33	23

Silvicultural Treatment

Finally, I would like to comment on silvicultural treatments. Following harvesting, invasion of herbaceous and shrubby species and the suckering of hardwoods are rapid and these species often out-compete desirable species. It has been shown that early successional species conserve nutrients through uptake which otherwise would be lost through rapid leaching (Likens et al. 1978, Boring et al. 1979).

Herbicides, paradoxically, can aid in structuring the development of a renewing stand, and at the same time, if used in sufficiently strong concentrations to denude an area, can result in substantial losses of nutrients from the ecosystem. On some sites these may be critically necessary to establish and maintain the early stand. Mechanical site treatment has been shown (Clemmer and Atkins 1979) to decimate advance growth of desirable species. It, too, will result in some nutrient losses.

Data presented here, however, provide some indication of the admissibility of site preparation in mixedwood sites. These sites appear rich enough to sustain it, particularly if some logging slash is left. Preferably, this would include the foliage and some of the small branches. These sites may even sustain it with whole-tree or biomass harvesting.

The application of fertilizer has been considered as a means of ameliorating losses expected from full-tree harvesting. Wells and Jorgensen (1979), however, comment that as more nutrients are removed in harvest and fertilizers are applied to stimulate growth, greater stress is placed on the soil for other elements. Multiple deficiencies are then produced as well as further increases in the complexity of predicting intensive harvesting effects.

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EFFECTS OF FORESTRY PRACTICES ON UNGULATE POPULATIONS IN THE BOREAL MIXEDWOOD FOREST

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Moose, white-tailed deer and woodland caribou all inhabit the boreal forest but, for a variety of reasons, the moose is the most likely ungulate to be found commonly utilizing boreal mixedwoods. The paper examines how various forestry practices affect the suitability of boreal mixedwoods as moose habitat.

Si la forêt boréale héberge aussi bien l'Orignal et le Cerf de Virginie que le Caribou des bois, l'Orignal est l'ongulé que l'on rencontre le plus communément dans les peuplements mélangés de cette forêt. Dans le présent document, les auteurs étudient les répercussions des différentes méthodes d'exploitation sur ces peuplements mélangés en tant qu'habitat de l'Orignal.

Three distinct species of ungulates--white-tailed deer (*Odocoileus virginianus*), woodland caribou (*Rangifer tarandus caribou*) and moose (*Alces alces*)--all members of the deer family, utilize portions of the boreal forest ecotone. The utilization of the mixedwood cover type in Ontario by these species is governed by their habitat requirements and by ecological and environmental factors.

Deer expanded their range northward into the boreal forest in the early 1900s following logging and land clearing (Cumming and Walden 1970). During extended periods of mild winters (i.e., winters with below-average snowfall) and where logging provided abundant food, deer moved as far north in Ontario as Kirkland Lake, Sioux Lookout and Red Lake (Euler 1979) (Fig. 1).

Leaves, stems and buds of woody plants are considered by many to be the mainstay of deer diet, mainly because they are available throughout the year (Halls 1973). The greater the variety of plants, the greater the chances for the white-tail to achieve its productive potential (Halls 1978). Deer feed on the leaves and tips of shrubs and trees including aspen (*Populus* spp.), cherry (*Prunus* spp.), mountain maple (*Acer spicatum* Lam.), willow (*Salix* spp.), bearberry (*Arctostaphylos* spp.), hazel (*Corylus* spp.), honeysuckle (*Lonicera* spp.), juneberry (*Amelanchier* spp.) and a great variety of herbaceous plants. In winter (the most critical season), they browse on the woody vegetation of trees and shrubs. During this period, the average deer requires approximately 2.3 kg of good quality browse per day (Smith and Borczon 1977).

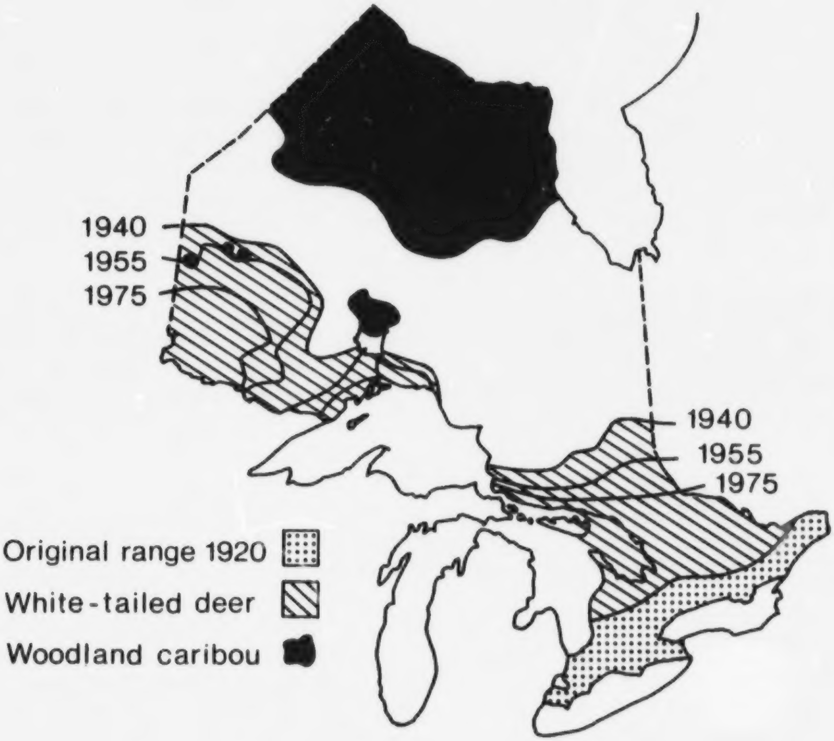

Figure 1. Changes in the white-tailed deer distribution from 1620 to 1975 (Smith and Borczon 1977) and the present woodland caribou distribution (Bergerud 1978) in Ontario.

Logging opens the forest canopy, and as a result there is more food available for deer. Adjacent mature stands of eastern white cedar (*Thuja occidentalis* L.), spruce (*Picea* spp.), balsam fir (*Abies balsamea* [L.] Mill.) and pine (*Pinus* spp.), if left uncut, provide the shelter needed in winter. However, the population densities of deer in the mixedwood component of the boreal forest depend primarily on the depth to which snow accumulates during winter, the duration of the snow cover and the suitability of range conditions following logging. Winter weather and the increasing size of clearcuts have been generally unfavorable for deer inhabiting the boreal forest areas since 1955, and as a result, both the range (Fig. 1) and local population densities have decreased.

Most woodland caribou in Ontario, of which an estimated 13,000 remain (Simkin 1965), are found in the northern, unlogged boreal forest and the Hudson Bay lowlands. A few scattered local herds survive in the commercial forest zone along the north shore of Lake Superior, north of Lake Nipigon and in the Irregular Lake area northwest of Kenora (Bergerud 1978) (Fig. 1). For many years, the disappearance of woodland caribou in this area has been attributed to environmental changes such as forest fires, settlement and logging. More recent evidence suggests that hunting mortality, disease and predation also play an important role.

Woodland caribou are gregarious and prefer to use the more mature boreal forest habitats (Cringan 1957). Tree and ground lichens are important winter foods. Caribou eat a wider variety of plants than do other deer species and are highly adapted, as well as adaptable, to their environment (Bergerud 1978). A partial list of plants eaten includes 282 kinds of seed plants and 62 lichens as well as green vascular plants and mushrooms.

During summer, caribou concentrate on the leaves of deciduous trees and shrubs, especially those of willow, birch (*Betula* spp.) and blueberry (*Vaccinium* spp.). During the fall after abscission, the animals switch to terrestrial lichens and leaves of coniferous species (Bergerud 1978). In winter, caribou frequently "crater" (dig down through the snow) to reach lichens and vascular plants. They also seek the fine twigs of browse species such as birch, willow, cherry and blueberry, and may utilize closed canopy habitats, when these are available, in search of arboreal lichens growing on coniferous and some deciduous trees.

The moose is well adapted to the boreal forest (Fig. 2), where important habitats are produced in the early seral stages of plant succession (Krefting 1974). Habitat, according to Franzmann (1978), is the primary limiting factor of moose populations throughout their North American range. The reproductive potential of moose is adapted to maintenance of the species at low densities (<1/5 km^2), rapid expansion into larger areas of good habitat following fire and logging (1/km^2) and slow contraction following forest maturation (Geist 1974).

Large quantities of forage (18-25 kg/day) are necessary to maintain an adult moose (Gasaway and Coady 1974). Mixed stands of conifers and hardwoods in continuous succession are favored (Pimlott 1953, Peterson 1955, Dodds 1974). In winter, moose tend to select sites where snow depths allow for bedding in comfort and do not restrict movement to feeding areas (Dodds 1974).

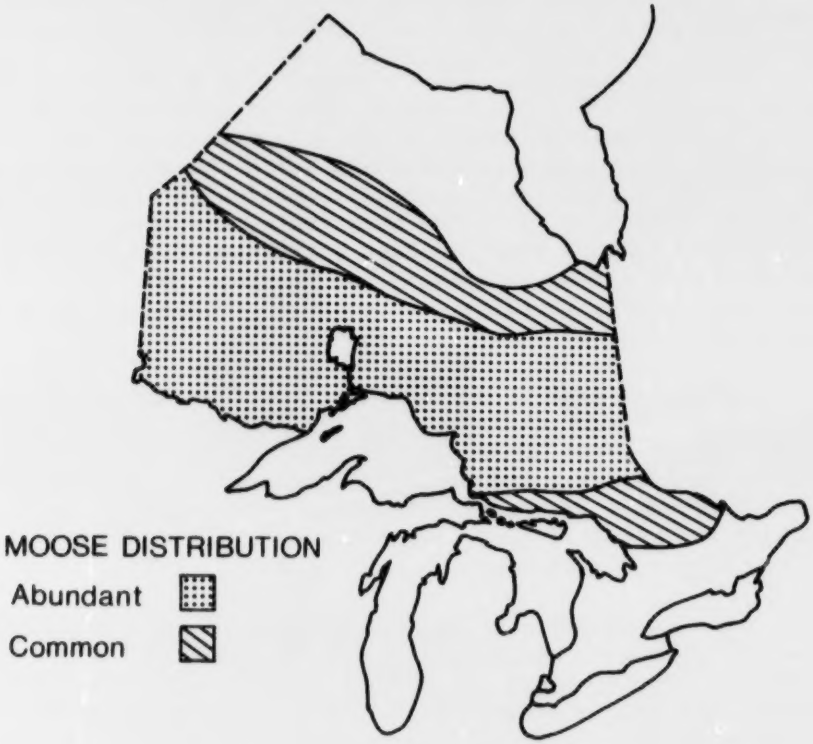

Figure 2. Moose distribution in Ontario (Cumming 1972).

Key browse species in eastern North American moose range are balsam fir, white birch (*Betula papyrifera* Marsh.) and trembling aspen (*Populus tremuloides* Michx.). Hazel, mountain maple, mountain ash (*Sorbus americana* Marsh.), willow, juneberry, dogwood (*Cornus* spp.) and cherry are other major browse foods. In summer and early fall, habitat use is centred on upland deciduous tree stands (Krefting 1974).

In early winter, young successional mixedwood stands created by disturbances such as fire, budworm or logging are preferred. As the winter advances and snow depths increase, moose gradually shift their habitat from open mixedwood stands to denser coniferous cover (Des Meules 1965, Telfer 1970, Peek 1971). The latter, consisting primarily of balsam fir and spruce, provides the moose with shelter during this critical period of the year.

Wildfire and logging have generally benefited moose by providing large areas of early successional growth containing a much greater variety and quantity of food than mature forests (Cumming 1972). Moose populations generally increase in such disturbed areas (Aldous and Krefting 1946, Krefting 1951, Spencer and Chatelain 1953, Peterson 1955, Peek 1971). Over the past 15 years wildfire has generally become a less important factor in the creation of early successional stages because of man's increasing efforts to prevent and suppress forest fires.

Timber harvesting, on the other hand, has increased in importance as a major disturbance factor in the boreal forest over the same period. Timber harvesting is currently the most predictable major disturbance in the boreal forest. Meaningful habitat management of boreal ungulates, primarily moose, is dependent on the recognition by forest managers of the need in some areas to maintain a variety of habitats through the modification or restriction of some forestry practices. An examination of how such practices in boreal mixedwoods affect moose will illustrate how forest management can either benefit or hinder habitat management goals.

Timber Harvesting

The preceding discussion on the habitat requirements of moose indicated the importance of a diversity of woody vegetation types and age classes within the animal's normal range. Timber harvesting in boreal mixedwood types can enhance the inherent species and age class diversity of these stands. The removal of the mature coniferous component from conifer-dominated stands, while leaving the mature deciduous component and advance coniferous regeneration, results in good moose habitat for several reasons:

1. Opening the canopy allows the establishment of important shade-intolerant browse species such as white birch and trembling aspen, which augment shade-tolerant browse species already in the understory.

2. The residual deciduous component provides immediate age class diversity on the disturbed site in addition to escape cover and increased "edge".

3. Advance coniferous regeneration in the cutover provides immediate early winter cover, escape cover and vegetational species diversity.

The boreal mixedwood forest type alone has the potential to offer moose this variety of habitat advantages, provided that only the mature coniferous component is harvested. Welsh et al. (1980) found on study areas in the Chapleau Crown Game Preserve that, in midwinter, with a choice of a variety of cut and uncut habitats, moose preferred cutover mixedwood stands from which up to 40% of the original composition had been removed.

McNicol and Gilbert (1980) reported that within 16 boreal mixedwood cutovers they studied in the Thunder Bay area, moose habitat utilization during January and February was concentrated in areas supporting a scattered residual coniferous and deciduous component (basal areas equal, at approximately 2.5 m^2/ha). Results from this study showed that the scattered residual cover type produced a much greater abundance and diversity of browse species (10) than did the three other available cover types delineated within the cutovers. Except for the dense conifer cover type (residual blocks of unmerchantable conifer), the other less productive cover types were characterized by the absence of a mature or semimature residual component.

An abundant and diverse browse source is an important element of good moose range, particularly in winter. Browse consumption by moose at this time is generally lower than in summer (Le Resche 1970, Verme 1970), probably because food is less digestible and is therefore retained longer in the rumen, as has been noted for other ruminants (Corbett 1969). Under winter conditions, about one third of the energy metabolized by moose may have to be provided through the catabolization of body fat and protein reserves (Gasaway and Coady 1974). The movements necessary to collect enough browse to maintain rumen-fill may require significant energy expenditures, especially if snow conditions are limiting to moose movement. An abundant browse source reduces the energy expenditure necessary to collect browse.

A selection of different browse species is important since changes in snow conditions can cause major changes in the species which moose prefer to browse (Peek et al. 1976, McNicol and Gilbert 1980). A variety of browse species consumed in the winter diet probably enhances the digestibility of this fibrous food source as well (Mellenberger et al. 1971).

The coniferous component which often develops in the understory of boreal mixedwood stands seems to be important as both escape and survival cover for moose following the harvest of the mature conifer component in these stands. Moose bed an average of five times a day (Franzmann et al. 1976), probably to ruminate, as do domestic ruminants. Studies in Quebec (Des Meules 1965) and Ontario (McNicol and Gilbert 1978) show that moose prefer to bed within 2 m of coniferous cover when utilizing open habitats during the winter. Indirect evidence indicates that moose select bedding sites in close proximity to immature coniferous cover on open habitats to reduce wind chill (McNicol and Gilbert 1978). Accumulated snow in the lee of these windbreaks often tends to be softer and more compressible since it lacks a wind crust (Des Meules 1965).

Advance coniferous regeneration, primarily balsam fir, is often found in close association with good browsing opportunities in mixedwood cutovers (McNicol and Gilbert 1980). Since browsing, bedding and ruminating are related activities, close proximity of food and vertical protective cover is an attractive feature of mixedwood cutovers.

The preceding discussion on the value of mixedwood stands after timber harvesting assumes a partial cut where only merchantable conifers are removed. This type of timber harvest has been common in boreal mixedwood stands in northern Ontario and has accidentally resulted in excellent moose habitat over many areas. Quite simply, the lack of deciduous fibre markets in many areas of Ontario has improved moose range. However, the same global demand for wood fibre which caused the liquidation of Ontario white pine (*Pinus strobus* L.) and red pine (*P. resinosa* Ait.) and the continued depletion of this provinces's spruce and jack pine (*P. banksiana* Lamb.) stands, has now focused on boreal hardwoods.

The results of the inevitable growth in the deciduous wood fibre market will be a substantial loss of age class and species diversity on boreal mixedwood sites. The loss of the mature hardwood component and destruction of browse and cover species in the understory during harvesting, will prove as negative for moose as previous cutting practices proved positive.

Clearcutting of boreal mixedwood stands will prove detrimental not only on a small scale (individual cutovers) but also on a large scale (license areas). Wildlife managers will no longer be able to rely on mixedwood stands to buffer large coniferous clearcuts. The result will give new meaning to the word clearcut, provided that timber companies do not adopt modified cutting practices on a large scale. The adverse temporal and spatial development of moose habitat on contiguously clearcut areas would limit moose populations.

Silvicultural Treatments

Boreal mixedwood forest types are often found on productive sites. A variety of silvicultural treatments may be applied by forest managers to encourage the regrowth of merchantable coniferous stands on these sites. The following comments relate to the beneficial or detrimental effects various treatments may have on moose.

Scarification: The practice of scarification after logging is common in northern Ontario. On mixedwood cutovers, scarification is generally carried out in preparation for the planting of jack pine, or more commonly black spruce (*Picea mariana* [Mill.] B.S.P.) and/or white spruce (*P. glauca* [Moench] Voss) seedlings.

Scarification followed by planting of coniferous seedling stock is an attempt by forest managers to truncate the normal successional sequence following disturbance on mixedwood sites. It is the early stage of succession following fire (3-20 years) which historically has supported growth in moose populations (Geist 1974, Irwin 1975). Logged mixedwood stands have the potential for supporting increased populations of moose for a similar period. However, scarification and planting tend to shorten this early successional stage and in turn may reduce the period during which these areas can support high moose densities (Telfer 1976).

Boreal mixedwood cutovers which have been completely scarified and artificially regenerated differ from those which follow a natural course of succession and retain unmerchantable trees (Telfer 1976). Results from studies in Alberta (Stelfox et al. 1976) and Ontario (McNicol and Gilbert 1980) indicate that in scarified areas the production of deciduous browse species is reduced and much delayed. Not only is the browse component on scarified mixedwood sites altered but conifer cover is affected as well. The coniferous species which are planted will eventually produce both early and late winter cover for moose. However, artificial regeneration does not duplicate the immediate habitat advantages of interspersed advance coniferous regeneration which would have survived if scarification had not taken place.

In the past, many mixedwood cutover sites were not extensively scarified and planted because of heavy residual concentrations left after the harvest of the coniferous component. If we assume an increased demand for deciduous fibre, there will no longer be such concentrations on many mixedwood sites after harvest. More extensive scarification on mixedwood sites will likely follow, compounding the degradation to moose habitat initiated with the removal of the deciduous component. Forest management agreements (FMAs) between private pulp and paper companies and the government provide incentives for the companies to increase conifer stocking on cutover sites. Since mixedwood sites are often the most productive, it would seem logical for the companies to concentrate silvicultural efforts, including extensive scarification and planting, on sites that could have been good moose range.

"Tunneling", a form of scarification that is used less commonly, normally improves moose range. This technique is used by forest managers to introduce a merchantable coniferous component into hardwood stands. Heavy scarification equipment is initially driven through the stand, usually in a strip pattern, and conifers are planted in the scarified strips. Such planting introduces diversity and will eventually provide early and some late winter cover, improving the stand as moose habitat (Telfer 1976).

Herbicides: These have proved useful in forestry for controlling stand composition, particularly in the early stages following logging or fire when forest managers are attempting to establish commercial species (Telfer 1976). Boreal mixedwood cutovers, because of the inherent productivity of the sites and usually abundant deciduous regeneration after disturbance, are often prime candidates for treatment. Chemical defoliants are also used on mature or semimature mixedwood stands in an effort to release advance coniferous regeneration in the understory.

The impact of herbicide applications and the utilization of treated sites by ungulates, primarily deer, have been examined by a number of researchers in the United States (Krefting and Hansen 1969, Beasom and Scifres 1977, Tanner et al. 1978). Apart from a temporary reduction in use (usually just the year of treatment), utilization of sprayed areas was either the same as, or better than, utilization of similar untreated sites.

Krefting and Hansen (1969) believed that aerial applications of 2,4-D could be effective in increasing browse production in areas where access or labor costs for cutting browse were problems. In Ontario, assessment of a burn in the White River area which was subsequently treated with a combination of 2,4-D and 2,4,5-T showed no selection by moose for sprayed or unsprayed areas 3 to 4 years after treatment (Barker and Malone 1972).

The effects of recommended application rates of herbicides such as 2,4-D and 2,4,5-T differ according to the browse species treated. White birch and pin cherry (*Prunus pensylvanica* L.f.) are often killed immediately, and there is little or no suckering to compensate for the loss. Mountain maple and mountain ash remain relatively unchanged, since suckering of these species replaces stems which are killed within three or four years (Barker and Malone 1972). The most common effect on the majority of browse species is a temporary setback, followed by subsequent regrowth.

The loss of pin cherry and especially white birch from treated mixedwood cutovers could significantly affect winter browsing activities by moose. McNicol and Gilbert (1980) found that white birch and pin cherry were two of five species most often browsed by moose utilizing the 16 mixedwood cutovers they studied. White birch twigs alone accounted for approximately 31% of all browse consumed by moose over two winter study periods.

Discussion thus far has centred on the use of herbicides to set back deciduous regeneration temporarily and "release" conifers. A less common use of herbicides is for stand conversion, where all deciduous competition in a mixedwood stand is killed through repeated applications of herbicides or where mixedwood cutover sites are completely "sterilized" with herbicides before conifers are planted. The ramifications of this drastic intervention into natural succession for moose and a variety of other wildlife species dependent on mid-successional forests are obvious. Mixedwood manipulation of this type must be considered carefully with regard to wildlife requirements within the affected area.

Prescribed burning: Accumulated slash and logging debris can be removed economically and effectively from cutover sites through the use of fire. Bunnell and Eastman (1976) suggest that, after prescribed burning, site damage is generally less severe than it is after wildfire and that slash burning should extend the early successional stages. In Maine, prescribed burning of logging debris in clearcuts resulted in greater production of hardwood stems, shrubs and herbaceous plants than in clearcuts where slash was left undisturbed (Rinaldi 1970). Stoeckeler (1948) reported that root suckering of trembling aspen, an important browse species for moose, was stimulated by light burns.

The benefits of a more nutritious browse source, as a result of the rapid return of nutrients to the soil, are probably short term (Einarsen 1946, Taber 1973). However, the rapid invasion of fire-disturbed sites by ungulates (Stenlund 1971) and heavy initial utilization of post-fire vegetation (Randall 1966) may be a response to an increase in quality as well as quantity of browse (Cumming 1972).

The beneficial effects for ungulates of prescribed burning in the Lake States may last 10-15 years before the canopy closes over (Krefting 1962). Ahlgren (1973) suggested infrequent (once per tree generation) use of fire in the Lake States forests because of thinner soils, slower accumulation of organic material, shorter growing seasons for competing vegetation and increased vulnerability to fire damage.

The use of prescribed burning as a silvicultural tool on boreal mixedwood cutovers could be beneficial to moose provided that most residual elements were not destroyed by the fire. The residual deciduous component with attendant understory is an important factor influencing the early use of boreal mixedwood cutovers by moose. Prescribed burning should take place when residual patches are relatively incombustible. In this way, the residuals could also help to improve fire control by ensuring discontinuity of combustible slash.

CONCLUSIONS

All forest harvesting and management activities in the boreal mixedwood forest type have an effect on boreal ungulates. The extent to which these activities are beneficial or detrimental to species such as moose or white-tailed deer is directly related to how radically and extensively the natural age class and species diversity of mixedwood stands are altered. Efforts by forest managers to short-circuit natural successional sequences over large areas in boreal mixedwood stands to create monotypic coniferous stands will prove detrimental to ungulate species dependent on successional forest types. On the other hand, a forest management approach which recognizes the value to the boreal ecology of a vigorous, prominent mixedwood component in the boreal forest will prove beneficial to a wide variety of boreal wildlife.

As the demand for wood fibre and recreation opportunities on the same land base increases, competition between resource managers because of different objectives will increase. It is extremely important that wildlife and timber managers be aware of each other's objectives for the boreal mixedwood timber type so that conflicts can be avoided.

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IMPACT ON BIRD POPULATIONS OF HARVESTING THE BOREAL MIXEDWOOD FOREST

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The boreal mixedwood forest has a rich breeding bird community of 150 species. Most are migrants and many winter in the tropics. Density and richness are controlled principally by factors not directly affected by selective cutting. Harvesting results in dramatic bird species shifts, some of which may be irreversible.

La forêt boréale mélangée abrite 150 espèces d'oiseaux qui s'y reproduisent. La plupart sont migrateurs et passent l'hiver sous les tropiques. La densité et la richesse de cette faune dépendent principalement de facteurs qui ne sont pas directement modifiés par la coupe sélective. L'exploitation de la forêt bouleverse cette faune en provoquant le déplacement de plusieurs espèces d'oiseaux, de façon irréversible dans certains cas.

One hundred and fifty different species of birds breed in the boreal mixedwood forest of eastern North America, making it the richest breeding habitat on the continent. About 85 species are terrestrial perching birds that are totally dependent on some stage of the forest for their livelihood. These birds are an integral part of the forest ecosystem and play a primary role in the regulation of many insect populations.

Almost all birds of the boreal forest are migrants and more than half of the land birds winter south of 30°N. Many of the species that feed solely on insects spend only three months in the north to breed and raise their young; those that feed on fruit and seeds as well as insects may remain up to five months. In mixed stands of coniferous and deciduous trees, densities of 600 to 1,000 pairs/km^2 are common, and in severe insect outbreaks numbers frequently approach 2,000 pairs/km^2. In contrast, jack pine (*Pinus banksiana* Lamb.) stands and lowland conifer forests support only 100 to 200 pairs/km^2, upland spruce (*Picea* spp.) may support 200 to 400 pairs/km^2 and the richest of mixed-age deciduous stands rarely have more than 600 pairs.

The exceptionally varied avian community of the mixedwood forest is due to the complex nature of the vegetation and the large number of plant species represented. The combination of coniferous and deciduous trees, uneven age and size composition, and the presence of shrubs provides a variety of opportunities that many different species are able to exploit.

The present paper covers three main topics: the concept of niche and how it relates to mixedwood birds, the question of bird density and species richness as affected by harvesting, and the different responses to cutting by a few representative species. All references to cutting are to selective harvesting of mixedwoods. The data on which the paper is based were taken from studies in Mildred Township on Newaygo Timber Company land and on American Can Canada Inc. limits northwest of Manitouwadge.

At this point I would like to define a few terms to ensure that my meaning is clear to everyone. *Density* refers to the number of individuals of any specified entity, usually a species or taxocene. *Richness* is the number of species of a taxocene in a community. *Diversity*, as the term is currently used in ecology, is an integrated measure combining richness and evenness. For example, two communities may each contain 10 species of trees but in the first case 91% of the trees are of one species and the remaining nine species each constitute only 1% of the total, while in the second case each species constitutes 10% of the total; regardless of the index used (and there are several) community two will have greater diversity because its component species are more evenly distributed.

One of the most interesting ecological questions is: "How can so many different bird species of similar size and diet co-exist?" The answer is that each utilizes a particular component of the forest or food resource more intensively or efficiently than other species. The unique place that each species occupies in the community is called its niche. In one of the most interesting bird families, that of the wood warblers, niche separation is based on vegetation structure as well as food resources.

An excellent general definition of niche was provided by Gause in 1934 in *The Struggle for Existence*. He wrote:

> "A niche indicates what place the given species occupies in a community, i.e., what are its habits, food and mode of life. It is admitted that as a result of competition two similar species scarcely ever occupy similar niches, but displace each other in such a manner that each takes possession of certain peculiar kinds of food and modes of life in which it has an advantage over its competitors."

Niche theory has become increasingly important in ecology in the last two decades following the description by Hutchinson (1957) of the niche as an n-dimensional hypervolume in which each measurable feature of the environment is given a vector in n-dimensional space. That portion of the space in which an individual's fitness is positive is its niche. At first it appeared that this theory could be tested but it was soon realized that one could never control the multiplicity of variables adequately. Nevertheless, it was possible to test some of the statements and corollaries based on this niche theory and an immense literature has developed on niche and competition theory.

Even though the environmental variables that could be used to describe a species' niche are apparently endless, in practice it has been found that a few variables will usually separate even closely overlapping species. In birds, food availability, food quality, climate, cover and nest site availability are the most important variables. In the forests of North America, foliage height, number of foliage layers, foliage volume, amount of open ground, tree species and density are the principal variables that have been used successfully to date to describe niche characteristics.

Niche is not an immutable fixed characteristic for any species, and all have some flexibility. Migratory birds have evolved a range of behaviors that lie within the morphological range of the species but allow them to adapt to a variety of habitat types, food abundances and competitive regimes. There is no law which says that an unfilled niche in any habitat must be left open for the species that normally fills it.

It is important to emphasize that there are three aspects of the bird community to be considered: density, richness, and composition. Habitats can have identical density with 1 or 25 species, identical richness and composition with 500 or 1,000 pairs/km^2, and identical density and richness with totally different species.

The density of birds in any habitat is related principally to food availability. In boreal mixedwoods most species are foliage gleaning insectivores and their density is dramatically influenced by insect density. This is clearly shown by the fact that increases of almost an order in magnitude are found at times of spruce budworm (*Choristoneura fumiferana* [Clem.]) outbreaks.

Figure 1 shows bird density in mixedwood forests of different ages for two locations. The most striking feature of the figure is that, although density varies in stands of different age, there is no consistent trend. Density is as great in some early successional mixedwoods as in old uncut stands, and in some it is greater. Also, the two areas, Manitouwadge and Mildred, have dramatically different densities; the difference is due primarily to a high budworm density in Mildred although geographic location may have some influence. Figure 2 shows species richness (the number of species) in the same areas. As is the case with density, species richness is greater on some sites than it is on others but there is no consistent trend with age.

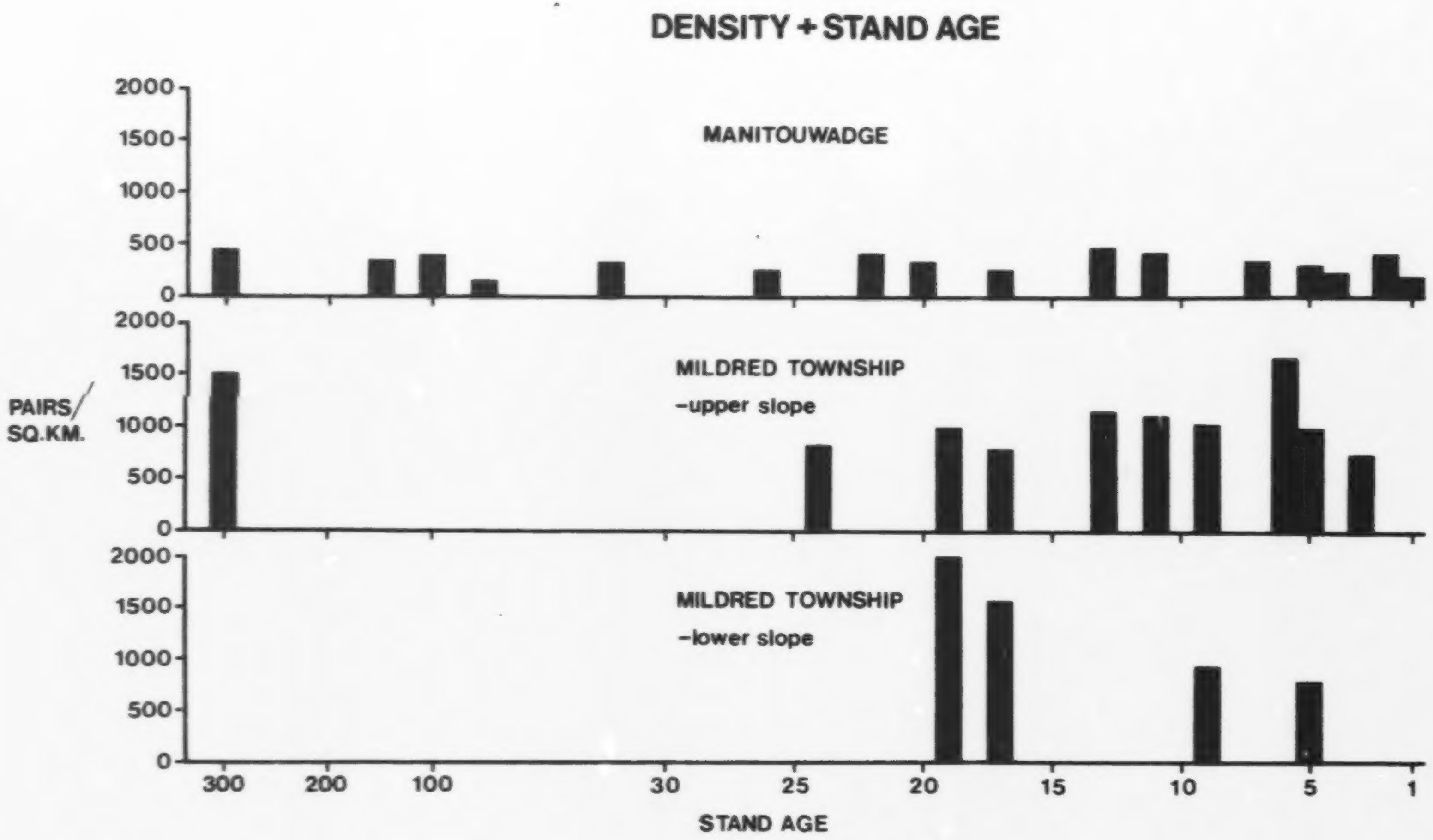

Figure 1. Total bird density related to forest stand age.

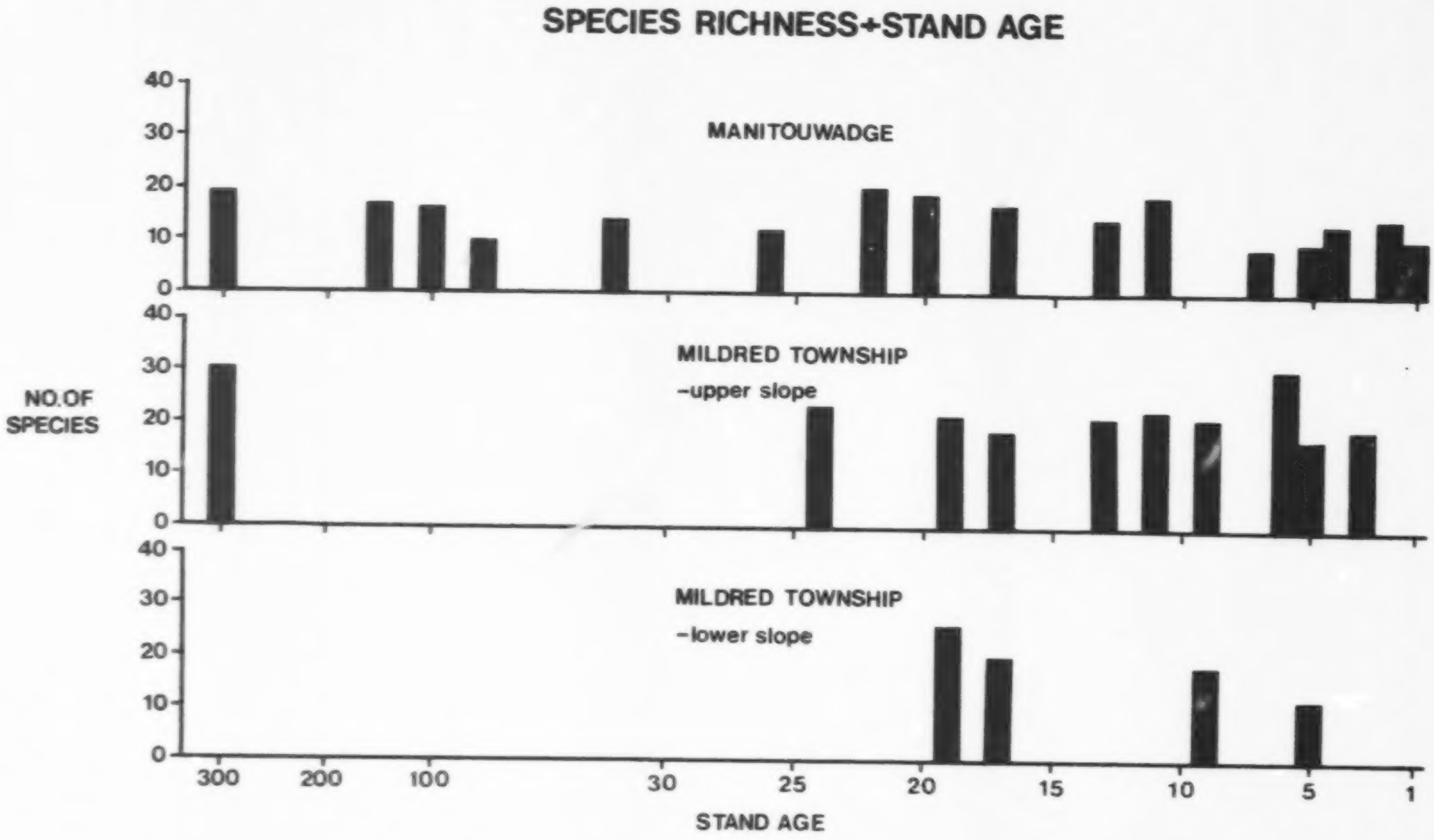

Figure 2. Bird species richness (number of species) related to forest stand age.

Birds are frequently classed in groups called guilds. The members of a guild coexist, exploiting the same class of environmental resources in a similar manner. The number of guilds and the number of species in each guild in any habitat are to a large extent controlled by the vegetation. Members of a guild are perhaps best thought of as birds with very similar niches. Most woodpeckers would be in the same guild, upper canopy flycatchers in another, and so on.

It is instructive to look briefly at a system for the classification of guilds. One of the more promising guild classifications was developed by Willson (1974) using primary food habits, foraging area, and foraging behavior.

The three levels with subclasses are as follows:

A) Primary food habits

  1) Seedeater
  2) Insectivore
  3) Omnivore

B) Primary foraging area

  1) Bark
  2) Ground
  3) Low canopy
  4) Middle canopy
  5) High canopy

C) Usual foraging behavior

  1) Bark drill
  2) Bark glean
  3) Ground glean
  4) Foliage glean
  5) Sally

Each species can then be given a three-digit number representing its guild. For example, a 255 would be an insectivorous high sallyer, a 235 would be an insectivorous low sallyer, and so on. Exactly which species of a guild will occur in an area depends on geographic location and details of the habitat, with occupation based on matching body weight, bill size, fine details of foraging behavior, and nest requirements to the habitat.

The effect forest harvesting will have on birds depends on the original stand composition and the type and amount of foliage change. The changes are best understood at the guild and niche level. If the structure of the habitat is changed dramatically then full guilds will be lost, while almost any alteration will change niches and affect the competitive balance between species, thereby resulting in species changes. Richness will increase or decrease depending on the nature of the changes, and the number of individuals will respond primarily to other variables.

The usual forest succession pattern is much simpler than that of the boreal mixedwoods and the bird response is more predictable. For example, development of a shrub layer adds two or three species (234 and 323). Later, as trees develop, the insectivorous mid-canopy foliage gleaners (234) gain three to four species but the omnivorous low canopy gleaners (324) lose some for a net gain of only one or two.

Each major successional stage following mixedwood cutting has a distinctive set of breeding species but the shifts are complex, because the forest is changing within an existing forest superstructure. Figures 3 to 6 show how different representative species can be related to stand age. Naturally they are responding to the host of factors that change with time, and not to age alone. The early seral group (Fig. 3) is clearly concentrated in the period from cutting to mid-successional years, while the mid-successional species in Figure 4 do best in stands 10 to 40 years of age. A number of species occur almost exclusively in the uncut older stands. The last figure (Fig. 6) demonstrates that some species are responding to variables that are not related to successional age in any obvious way. Table 1 provides a further example of the way the abundance of some representative species changes with stand age.

Bird communities are complex because there are many species co-existing in competition for limited resources. In addition, they are mostly migratory, so the relative proportions of each species vary from spring to spring. Keeping guilds, niches, density, richness and composition in mind we can now see the effect of harvesting the boreal mixedwood forest. Cutting changes the structure of the habitat, thereby altering the competitive interactions between species, and this results in marked changes in the composition of the bird community.

When conifers are selectively removed few if any guilds are lost but some species such as the Cape May Warbler, Blackburnian Warbler, and Golden-crowned Kinglet which depend on conifers will be drastically reduced or eliminated. Other guilds like woodpeckers may increase in number of species or density because of increases in the number of dead trees and amount of slash available. In general the early seral species are the most flexible and will tend to benefit most from cutting. As that portion of the boreal forest which is cut over grows, populations of late-succession species will continue to decrease. At the present time we do not know what the critical population sizes are but clearly we will have to monitor population status carefully.

The species that exist in any community are the result of unique historical and ecological circumstances. Those exact conditions are unlikely to occur again. The stands that are created by cutting are different from any which occur naturally and the bird communities that

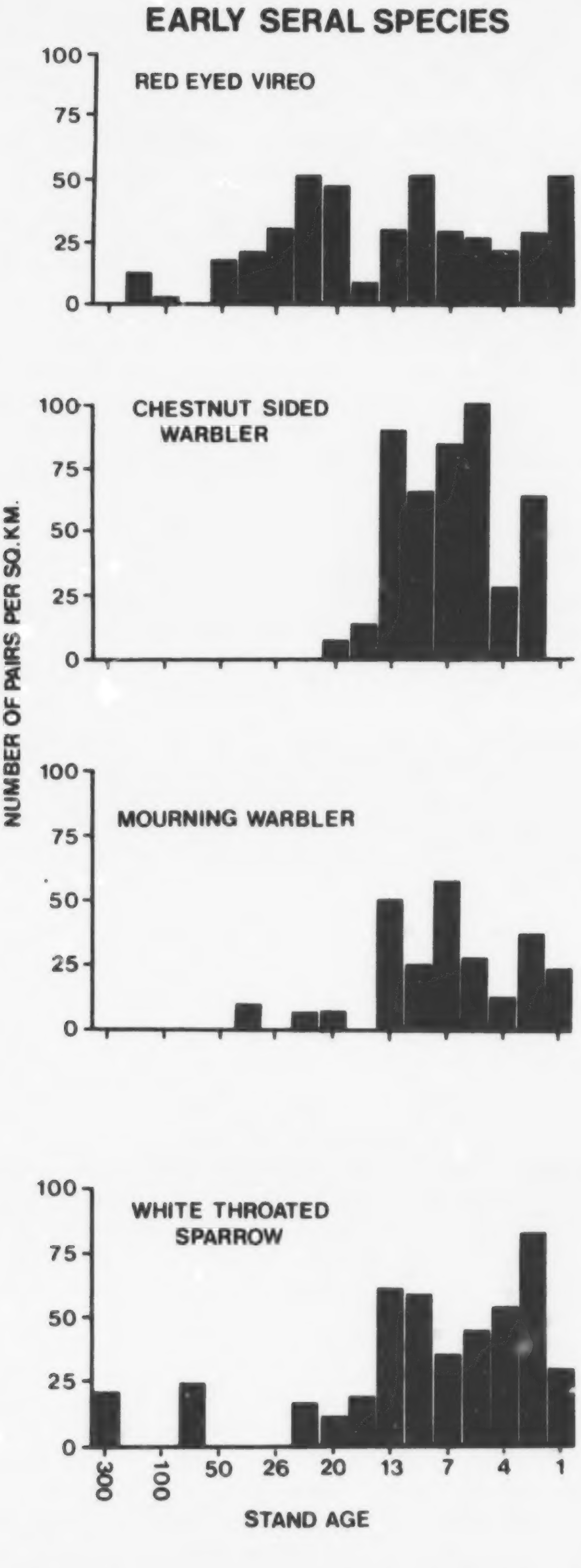

Figure 3. Density, in relation to stand age, of four representative early seral species.

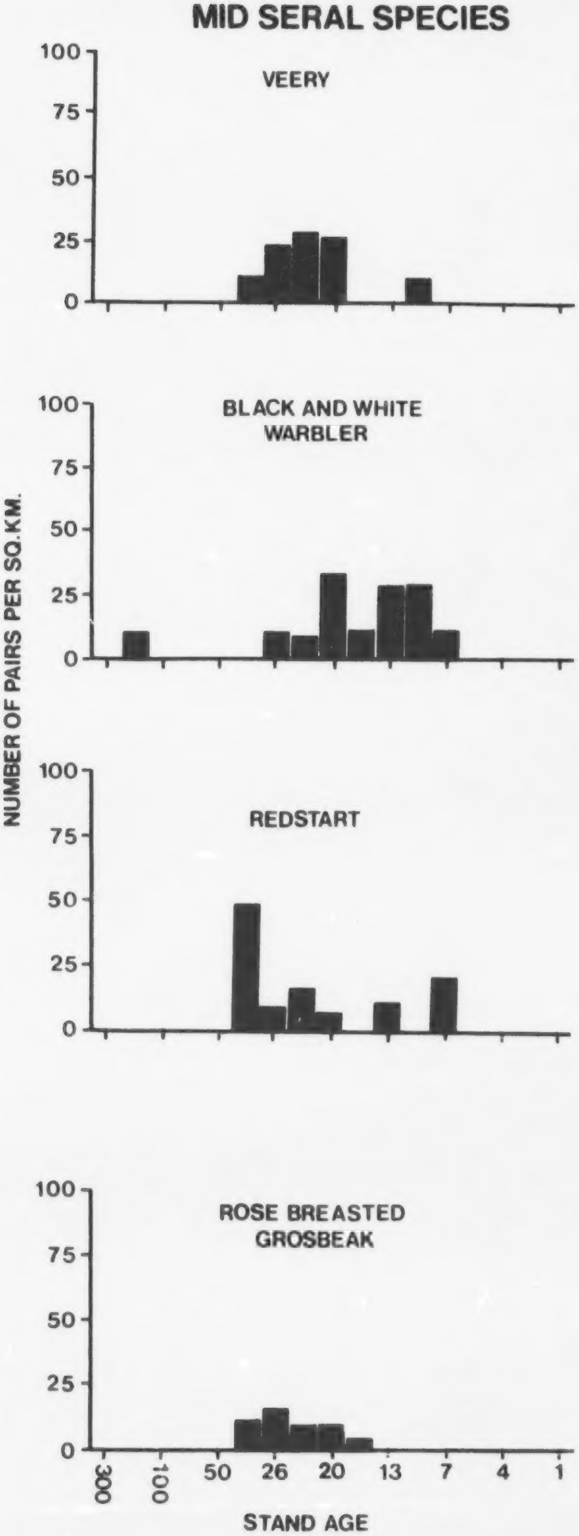

Figure 4. Density, in relation to stand age, of four representative mid-seral species.

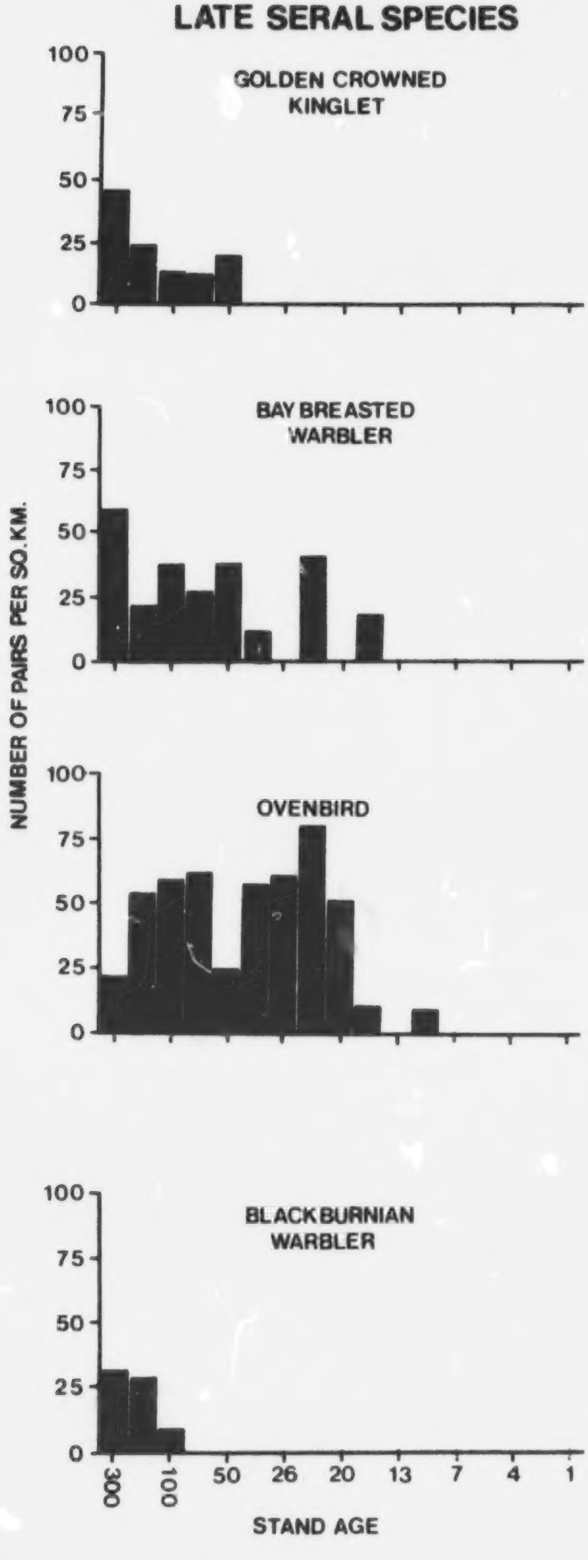

Figure 5. Density, in relation to stand age, of four representative late-seral species.

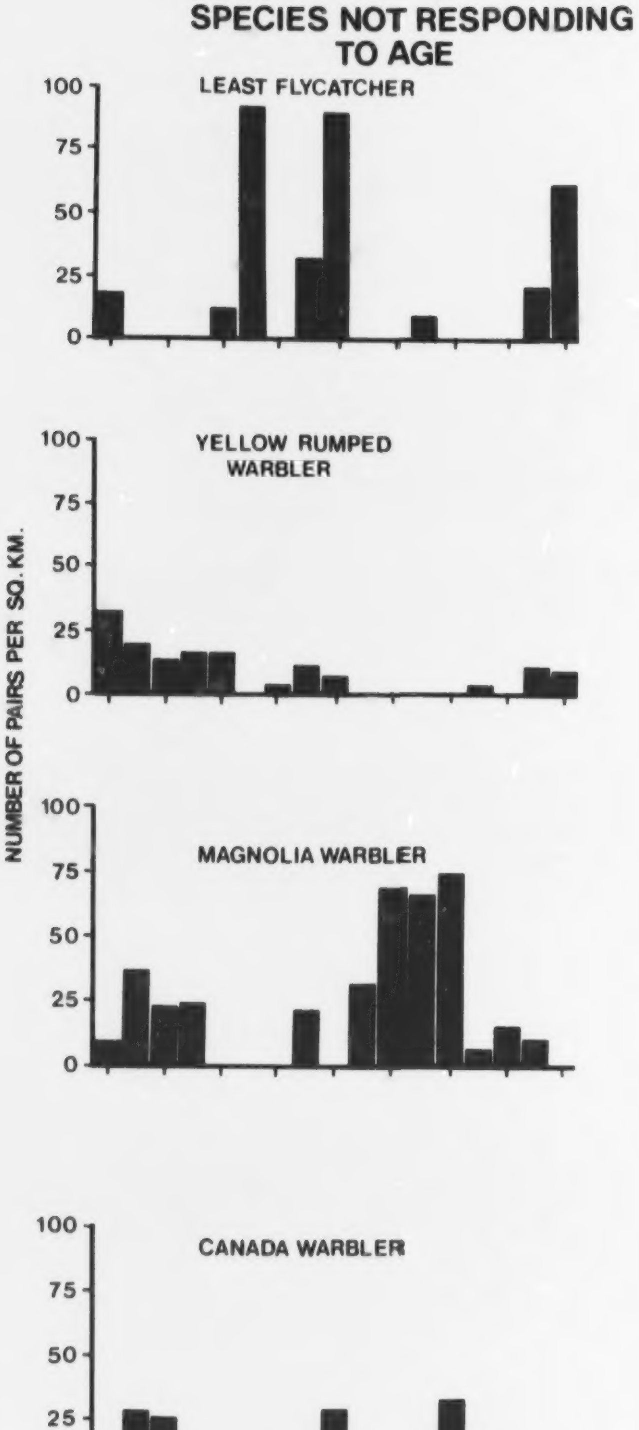

Figure 6. Density, in relation to stand age, of four species that do not respond to age.

Table 1. A comparison of some representative bird species densities (no. of pairs/km^2) in forest stands of different ages in two areas of northern Ontario.

	250-year-old stand		20-year-old stand		11-year-old stand	
	Mildred	Manitouwadge	Mildred	Manitouwadge	Mildred	Manitouwadge
Ruffed Grouse	5.6	--	33.3	--	22.2	11.1
Yellow-bellied Sapsucker	27.8	5.6	11.1	--	50.0	--
Alder Flycatcher	--	--	--	--	11.1	50.0
Least Flycatcher	56.1	56.1	--	88.9	11.1	11.1
Red-breasted Nuthatch	16.7	16.7	--	--	--	--
Brown Creeper	16.7	22.2	--	--	--	--
Winter Wren	16.7	11.1	--	--	--	5.6
Swainson's Thrush	33.3	56.1	39.0	--	--	--
Veery	--	--	11.1	27.8	67.0	11.1
Golden-crowned Kinglet	--	44.0	--	--	--	--
Red-eyed Vireo	22.2	11.1	100.0	44.0	111.1	50.0
Black-and-white Warbler	44.0	--	50.0	33.3	27.8	27.8
Tennessee Warbler	277.8	39.0	44.0	--	44.0	--
Nashville Warbler	156.0	16.7	11.1	16.7	5.6	22.2
Magnolia Warbler	222.2	27.8	100.0	5.6	61.1	67.0
Cape May Warbler	83.3	44.0	22.2	--	--	--
Yellow-rumped Warbler	33.3	33.3	--	5.6	--	--
Blackburnian Warbler	122.2	39.0	39.0	--	--	--
Chestnut-sided Warbler	--	--	72.2	5.6	405.6	67.0
Bay-breasted Warbler	11.1	61.1	--	--	--	--
Ovenbird	27.8	22.2	72.2	50.0	27.8	11.1
Mourning Warbler	5.6	--	44.0	5.6	61.1	22.2
Canada Warbler	44.0	11.1	16.7	27.8	11.1	11.1
American Redstart	--	--	--	5.6	106.0	5.6
Scarlet Tanager	5.6	--	11.1	--	--	--
Rose-breasted Grosbeak	5.6	--	--	11.1	11.1	--
White-throated Sparrow	72.2	22.2	--	11.1	72.2	56.1

develop in them as they mature will be new as well. Clearly they will not revert to what they were before harvesting and some species may be edged out entirely.

I think it is interesting to speculate about the effect these changes might have on prey species. In the past, in natural (i.e., not selectively cut) situations, as a successional stand grew older, species could move in from surrounding mature areas to take up residence. At the present time, in much of northeastern Ontario, the upper canopy is dominated by deciduous and generalist foliage gleaners that are well established in the upper canopy long before there are any conifers for the conifer specialists to occupy. When the trees finally grow it is unlikely that the birds' niches are still open and available.

For the sake of discussion let us assume that Cape May Warblers and Blackburnian Warblers normally feed heavily on spruce budworm (or any other prey, for that matter) as one of their foraging specialties and by so doing help to keep endemic populations in check. If we eliminate these species from a large area and, as a result of displacement, they have no niche to which they can return, then as conifers revegetate the stand, and budworm begin to increase, one of two things may happen. The new treetop foliage gleaners may learn to specialize in budworm and keep them in check or, alternatively, there may be no avian control at all. One cannot help wondering if we will see more and more insect prey erupting and crashing dramatically as a result of changes in competitive interactions in the predator class.

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Discussion

F.C. Robinson: Al Gordon spoke of the replacement time for nutrients after whole-tree or full-tree logging. Al, do you have any comments on how that might change if we went into further logging or removed the stumps or part of the roots? And if we went into quite short rotations--say, hybrid poplars with short rotation--or if we converted some of these mixedwoods to jack pine on a short rotation, what affect would it have on the nutrient cycling?

A.G. Gordon: If you remove the stumps and the roots it would make the replacement times longer and a whole lot of other things would happen as well. The roots contain a substantial amount of organic matter and nutrients. In the past we've estimated that the root sloughing is about equivalent to the leaf fall. New measurements suggest that those estimates are low and it looks as if root turnover is greater than leaf turnover--perhaps for a lot of other species as well. In my view you might be able to get away with it [removing stumps and roots] on the mixedwood sites, but I wouldn't want to try it on black spruce or jack pine sites, that is, on outwash plains. I just wouldn't want to see it at all.

As for short rotations, we've made some calculations and there are data from Wisconsin which indicate that the sites would not sustain 15-year cropping. Similarly, on the very richest and the best soils, phosphorus and potassium very quickly became limiting on short rotations. For the boreal system I think that short rotations in aspen will get us into trouble. We may be able to do it a couple of times but if we push the rotation up to 30 years it will be much better, and if we go to 45 years it will be better still. I wouldn't want to comment too much because we're basing some impressions on a series of plots which in our view gave us very low biomass and very low productivity.

J.R. Carrow: Al, you referred to the possible effects of herbicides on nutrient cycling and, if I understood you correctly, it's possible that continued herbicide use would reduce the quantity of nutrients returned to the ecosystem. I'd appreciate it if you would elaborate on that.

John McNicol, I was interested in your comments about balsam fir and the potential benefits for moose management, but it wasn't clear to me whether you were attributing those benefits (in the form of food) to balsam as a species or to immature conifers generally.

Dan Welsh, your comments about numerical response of some of these guilds to budworm outbreak were interesting to me and I wonder if you could expand on that? Is there any more precise information about the species that are responding, and will these species lend themselves to enhancement?

A.G. Gordon: Herbicides prevent the initial regrowth of species competing with desirable conifers on the site, and at the same time permit leaching, which is extensive in the first two years. Mechanical site preparation also contributes to erosion which, in turn, promotes leaching. In the case of ordinary clearcutting without herbicides nutrient losses are tremendous in the first two years. These losses gradually taper off at about 10 years but in that period, as I indicated, you can lose a hundred years of nitrogen input from the atmosphere. If you use herbicides the lag is longer--you get the same loss on the boreal mixedwood site because it has reserves. If you try herbicides in a jack pine and sweetfern stand on outwash sand plains, for example, where you want to get rid of the sweetfern you're going to deplete the site of nutrients, so it depends on where you use the herbicide. I would say you're best to use it on the mixedwood because of the reserve.

J.G. McNicol: Balsam fir provides both food and cover. All other coniferous species provide cover only.

D.A. Welsh: The whole thing is rather puzzling because the species that are responding to budworm during outbreak situations may not be the ones that keep them down during endemic situations. I'm not saying that they are necessarily different species; certainly, species like Tennessee warblers have been responding very dramatically in Mildred Twp--up to 4,000 pairs per square kilometre. There are studies going on right now by the Canadian Forestry Service and the Canadian Wildlife Service at Black Sturgeon Lake on the effect of endemic bird populations on budworm which may answer some of these questions. If we could recognize the key species and demonstrate that their predation is an important factor at low levels then we'd be well on our way. It is well established that birds are important predators on a number of insect species, and although it has yet to be demonstrated that they provide important controls on economically interesting insect species, it's only a matter of time until their role will be proven. Once that happens we may be able to use them for management purposes by enhancing their nesting areas to make sure we have adequate density. This is a few years down the road but it is worth attempting.

G. Brown: I would like to correct a misconception on the part of game managers about monocultures. We're trying as forest managers to maintain a species composition in the boreal forest which is about two-thirds conifer and one-third hardwood and they may be pleased to know we're not doing such a good job of it. Roughly speaking, our success rate in maintaining the conifers in the treated areas is about 74% in the pine working group, and about 90% in the spruce working group. The difference of 26% from jack pine automatically moves into the mixedwood or the ideal moose habitat and 10% from the spruce working group automatically goes to a succession stage in the balsam working group so you've got lots of moose cover and lots of browse. That's for the treated area. On areas that we don't treat because of lack of funds and what have you, the picture is a little more conducive to wildlife management.

If you don't treat the pine working group but permit natural succession to take place, only 22% will regenerate to jack pine; about 67% of the spruce group will regenerate to spruce, and again the area differences will go back into the mixedwood working groups or the poplar working groups. So don't worry about running out of moose grub or moose range or moose cover; as long as we haven't enough money to treat all the area we don't cut.

R.J. Day: Dr. Gordon's comments really troubled me. I happen to know we have an MSc thesis candidate sitting here in the audience on whose study area I applied a wide range of herbicides. The following year foliar nitrogen levels on the herbicide areas were considerably higher than those on any of the controls and such response is a common phenomenon. It's related to the decomposition of the root systems where plants have been killed. Now I'm a bit troubled about the idea that herbicides automatically lose a hundred years of nutrients. I just came from the top end of the Spruce River Road and was working in many areas that were sprayed in 1979. I waded in big leaf aster thigh deep. I've treated stands on many occasions only to find there's a shift from perhaps the aspen component to another component with extremely vigorous growth. If in fact the nutrient capital has been depleted for a hundred years, then what's happening--are we growing on air?

A.G. Gordon: All those observations are accepted. What I said was in reference to the application of herbicides to areas that have been totally devegetated, where you're not observing this herbaceous and other growth in the year following cutting. The loss of nitrogen is not measured in the foliage of the new growth because you can go and plant spruce on the site and get a huge pile of nitrogen. I said that what is lost through leaching is an amount equivalent to the input over a hundred years--we're not even talking about the same nitrogen. Those reserves to which you referred are still in the soil after herbicide application and you can get a flush of growth from them because they represent a special concentration.

R.J. Day: I'm really disturbed. I haven't yet found a totally devegetated area in the boreal mixedwood. I guess there is a rock, an erratic boulder somewhere to which your theory might apply.

M. Roberge: Do you think that the strip clearcutting system with one out of three strips cut now, a second one in 10 years and the third another 10 years later, could reduce the adverse impact on nutrient cycling and ungulate or avian populations to an acceptable level? What if this were followed by a well conducted release of the softwood regeneration, thus speeding up the successional stage to get the final softwood cut at rotation age?

J.G. McNicol: Is the question related to strip cutting on a lowland strip cut, or on upland?

M. Roberge: On a mixedwood site.

J.G. McNicol: On a mixedwood site, yes. Is this something you are practising?

M. Roberge: Well, we are doing it quite a bit in Quebec, yes.

J.G. McNicol: Do I understand you correctly? Are you cutting over a 30-year rotation--three strips over a 30-year rotation?

M. Roberge: 20 years--well yes, 30 years, in fact.

J.G. McNicol: Yes, I think that would be very beneficial. There's no reason why it shouldn't benefit the moose population. As a matter of interest, have you been doing this for awhile, and have you been able to quantify any results of that particular management practice, as far as benefits to the moose population are concerned?

M. Roberge: No, not yet, but we are looking at it. We want to keep our mixedwood forests in mixedwood, or with a large softwood component, and at the same time provide something good for the soil, the water, the birds--everything.

J.G. McNicol: I think that is an excellent idea. I don't want to let you get away. It's so unusual to hear anyone talking about partial cutting in mixedwoods. In terms of economics, are you finding it economically viable?

M. Roberge: As far as cost is concerned, roads are the major item, of course, but in most cases the roads are already there. Also economics are improved from the view of utilization of trees that we cannot otherwise utilize.

J.G. McNicol: Excellent.

G. Pierpoint: My question is related to Dr. Roberge's question to John McNicol. Obviously strip cutting or patch cutting is an approach to forest management that favors the ungulate population. I think that came through quite clearly from what you said. My question is: If, in fact, managers or the companies cut in patches or strips, what is the minimum time you would recommend before removing the remaining uncut patches and strips in order to ensure a satisfactory carry-over of habitat conditions for the ungulate population? what is the minimum satisfactory time we have to wait before going back in to remove the uncut stand, specifically the mixedwood stand?

J.G. McNicol: In mixedwood stands it's not too critical. When you're looking at modified harvesting in conifer stands and your objective is the maintenance of late winter cover, turn-around times become more important because once you remove, say, 0% of a very important element of late winter cover within a particular area and then come back in 5 or 6 years to remove the rest of it, essentially you have removed all of the late winter cover in that particular area. For mixedwoods that you're trying to do is maintain the diversity of the mixedwood type so turn-around times of 5-10 years would probably be suitable.

G. Pierpoint: What about the other forest types with more conifers? What's the minimum time you'd recommend there?

J.G. McNicol: Well, as company people will tell you, there are economic problems involved in leaving lowland spruce sites or upland spruce sites for significant periods of time. You also have blowdown problems on fragile sites, especially upland sites, so you have to look at all the parameters involved. Ideally, if the site is not subject to blowdown and maintenance of the road system is not a critical issue, I would say 15-20 years.

D.E. Ketcheson: John, if you could magically cause all of the cutting of the North Central Region next year to be done by the strip cut method or alternate strip cut method, within the next 5 years what kind of increase in the moose population would you expect to see?

J.G. McNicol: I would like to pass this question along to Tim Timmermann, Regional Moose Biologist of the North Central Region.

H.R. Timmermann: Significant restrictions concerning the harvest of moose by recreational hunters will be instituted this fall. We are hopeful that these restrictions will help reduce the harvest of moose and allow the remaining standing population to achieve its potential and increase. Modified cutting will certainly enhance the habitat and along with a more predictable harvest and control of hunters we are confident that a significant increase in the moose population, perhaps in the order of 25%, can be achieved in the next few years.

SESSION V: CURRENT MANAGEMENT PRACTICES IN THE BOREAL MIXEDWOOD FOREST

Site preparation "tunneling" in a boreal mixedwood stand near Manitouwadge, Ontario.

SESSION V: CURRENT MANAGEMENT PRACTICES IN THE BOREAL MIXEDWOOD FOREST

Introduction (*D.H. Weingartner*)

Yesterday on the field trip we took a journey through time. You may not have realized it, but we looked at the past, present and possibly the future trends in management practices for the boreal mixedwood forest. The past was represented by the undisturbed boreal mixedwood, where the management techniques were the forces of nature. The present was represented by the current techniques that are frequently applied to the boreal mixedwood and are familiar to us all (i.e., site preparation followed by planting for spruce regeneration, and clearcutting for aspen regeneration); and the future trends may have been represented, in part, by the intensive tending techniques that produced the excellent white spruce we observed in the afternoon.

This morning's session, entitled "Current Management Practices in the Boreal Mixedwood Forest", addresses the present and will feature a local view of harvesting practices, a regional view of management practices and a provincial view of management needs. Even though this session deals with current management, its most important function will be to provoke thought and discussion, so that we can take a step into the future management of the boreal mixedwood forest.

PRESENT HARVESTING PRACTICES BY GREAT LAKES FOREST PRODUCTS LIMITED IN THE BOREAL MIXEDWOOD FOREST IN NORTHERN ONTARIO

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Over the past 50 years, increasing demands for wood fibre have forced us to mechanize our woodlands operations in order to supply mills and other wood-using firms with pulpwood fibre and by-products. In this paper the application of three mechanized logging systems to mixedwood stands up to 150 km from the mill is discussed. The author is optimistic that our woodlands can fill all future mill fibre requirements from our licence area with the help of new Forest Management Agreements.

Au cours des 50 dernières années, nous avons dû mécaniser nos opérations forestières pour être en mesure de répondre à la demande croissante de cellulose de l'industrie des pâtes et papiers et des autres secteurs qui utilisent la fibre ligneuse et ses sous-produits. Dans ce document sont discutées trois méthodes d'exploitation mécanisée des peuplements mélangés situés jusqu'à 150 km de l'usine. Nous sommes persuadés qu'une nouvelle politique d'aménagement forestier permettra à nos boisés de répondre à tous les besoins futurs en fibres.

The licence of Great Lakes Forest Products Limited lies within the Boreal and Great Lakes-St. Lawrence forest regions. Upland sites surrounding Thunder Bay were logged for white pine (*Pinus strobus* L.) around the turn of the century. Large pine cuts were also made around the Lake of the Woods area, and these supplied the mills at Rat Portage (now Kenora). With the demise of the square timber trade in the east, the shantyman, who broadaxed white pine, migrated westward. In passing through Ontario, he brought new life to the area, for he was instrumental in supplying jack pine (*P. banksiana* Lamb.) ties for the railways. A kilometre of track required from 4,160 to 5,120 ties, and railway construction from 1880 to 1910 created a considerable demand.

The pulp and paper industry got its start in the early 1900s. Most of the pulpwood requirements were met by black spruce (*Picea mariana* [Mill.] B.S.P.) on wet sites. The upland sites were harvested solely for sawlog material, which was used in the portable sawmills that were set up to build the 100-man bush camps.

The Great Lakes Paper Company Limited was founded in 1919. In 1928 it was consuming fewer than 1,080 cu. m of spruce per day. By 1958, newsmill consumption was 4,320 cu. m per day. A bleached Kraft mill was added in 1966 and consumption rose to 9,000 cu. m per day, but 50% of this daily consumption was jack pine.

It can be seen, therefore, that the company's species requirements have changed considerably since the early years of the century. In addition, the demand for wood fibre from our supply area has increased rapidly in the past 20 years. In 1973, a stud lumber mill was added and in 1975, a waferboard-particle board mill which uses approximately 324,000 cu. m of poplar (*Populus* spp.) began production. Our last Kraft mill expansion came in 1975, when we nearly doubled our daily consumption to 15,480 cu. m per day. Our present mill requirements are approximately 46.8 million cu. m of conifers per year plus 324,000 cu. m of poplar which we use in the waferboard-particle board plant, and 216,000 cu. m of by-product material (Table 1).

This increased demand for pulpwood by our mills necessitated the utilization of fibre from those upland sites that had been previously bypassed because of low spruce content, overmaturity, rot, etc. Some of the ways in which we increased limit supply were by establishing operating camps on a year-round basis, building all-weather roads, increasing productivity by mechanization, and sorting for various species.

Let us look back at a typical logging season in the 1920s (Table 2). A seven-day cutting operation took place over a 6-month period from June to December. A cutter was expected to put up 7.2 cu. m per man-day. A camp that was to produce 108,000 cu. m per season usually operated with 100 men. Ice roads were made in December and January to transport the wood to rivers or lakes by horse and sleigh for the spring drive to the mill in May and June. Much of the pulpwood came from the lowlands.

Today, our company has a heavy logging commitment on the upland sites as well. You may ask, "Why log these mixedwood stands?" The answer is that we cannot afford to bypass these highly productive sites which grow the largest material and furnish up to 30% of our mill requirements. These stands constitute 33% of the productive area that lies within 160 km of the mill. Today, we sort by-products at the stump with skidders, or slashers sort out log and tie material at roadside, and we use our better logging methods in the low-yield stands. For economic reasons we have been forced into greater utilization of the wood resources of our licence.

Table 1. Evolution of daily consumption, Great Lakes Forest Products Limited (in cu. m).

		News	Kraft	Poplar	Total
1928	1 news machine	1,080			1,080
1958	4 news machines	4,320			4,320
1966	add Kraft mill "A"	4,320	4,680		9,000
1973	add stud mill	4,320	5,760		10,080
1975	add Kraft mill "B" add waferboard mill	4,320	10,440	720	15,480

Wood use, 1979

	spruce	1,800,000	
	balsam fir	72,000	
	jack pine	2,160,000	
	chips	648,000	
Total:	conifer	4,680,000	
	poplar	324,000	
	by-products	216,000	- to Abitibi-Price Inc. Great West Timber Laidlaw

Harvesting practices in today's mixedwood forests include three mechanical methods of logging. These methods were developed for clear-cutting even-aged (coniferous) stands but have been modified to log selectively (in mixedwood stands) as well.

Shortwood system: This is a method of processing trees into 8 ft (2.8 m) lengths at the stump and forwarding them to roadside for temporary storage. The Koehring shortwood harvester is an example of the equipment we use which is heavily dependent on a sophisticated backup system of highly trained mechanics and operators, and requires good-sized wood. We have 41 such machines on our limits, working double shifts for 248 days of each year. Our average yield is 72 cu. m per man day, a far cry from the 7 cu. m per man day of the 1920s.

Table 2. Example of 1924 pulpwood operation[a] for 36,000 cu. m.

Employees	Wages	Total
1 office accountant	12 mo. @ $200	$ 2,400
1 camp foreman	6 mo. @ 150	900
1 camp clerk	6 mo. @ 75	450
1 scaler (½ wages)	6 mo. @ 90	540
1 cook	6 mo. @ 100	600
3 cook helpers	6 mo. @ 50	900
1 tote teamster	6 mo. @ 65	390
32 cutters	6 mo. @ 2.50 per 3.6 cu. m	25,000
24 haulers	4 mo. @ 1.25 per day	12,500
40 river drivers	2 mo. @ 4.00 per day	9,600
10 raftsmen	2 mo. @ 3.00 per day	1,800
1 tug man	2 mo. @1,000.00 per mo.	2,000
		$57,080

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[a] Camp operates 6 months: hauling 4 months, drive 2 months.

Treelength system: This is a method of severing the tree from the stump, limbing it and forwarding it to roadside for slashing at some future time. The wheeled skidder is the usual machine, producing over 25 cu. m per man day. The Drott feller with manual limbing and grapple forwarding is another system we use; it produces up to 43 cu. m per man day. A third system, the John Deere feller plus a grapple skidder, produces an average of 50 cu. m per man day on two-shift operations.

Full-tree system: This is a method of severing the tree from the stump and forwarding stem branches and top to roadside for future processing. We have just begun to use this method at one of our units, but it shows great potential for use in further processing at concentration points, including sorting and measurement of species and by-products, debarking, and chipping for transportation to a conversion plant. The Koehring Feller-forwarder and Roger Delimber are used at Graham. These units produce about 58 cu. m per man day.

The three methods described constitute a systems approach and are dependent on cu. m per ha, trees per cu. m, and ground conditions, as well as economies of size. A typical operating unit is planned to produce 294,000 cu. m per year using 10 wheeled skidders, five Koehrings, 10 trucks per 150 km haul (an average haul), two bulldozers and one slasher, with 90 men and seven supervisors.

The operating unit works 248 days a year, and certain pieces of equipment such as the Koehrings and trucks are used for two shifts. The annual operating plan requires 1,400-1,600 ha depending on how many low-yield mixedwood stands are to be harvested. Most of the cutting systems must move at least eight times per season. We attempt to minimize moving by staying in one set for two months, producing approximately 28,800 cu. m from 140 ha. The operating unit will build 16 km of all-weather gravel roads, 24 km of winter roads and 48 km of summer access roads. Most of our operating units are set up for at least 15 years.

The advantages and disadvantages of these systems in operational situations on upland sites are discussed in the following sections.

Economics

The fully mechanized systems are used with a view to producing pulpwood as cheaply as possible. Therefore, the best systems are considered to be those which ensure high productivity. Operational efficiency is due mainly to high yield per ha. This tends to decrease the size of the logging area and hence decrease road costs. The use of low-yield mixed upland sites is restricted with these systems except under special conditions (e.g., if particular species are required or the site is readily accessible). Generally, Koehrings and Drotts are the most economical in pure, even-aged conifer stands, for they harvest between 36 and 54 trees per cu. m. Forwarding distance for Koehrings is kept to a minimum because of a charge-out rate of $1.35 per minute. Skidder systems are the most versatile to operate, but they are labor-intensive and accident prone, and cost the company higher fringe benefits than other logging systems. The charge-out rate for skidders is 58¢ per minute. An average skidding distance of 200 m is normal; however, distances of 500 m are not uncommon in low-yield mixed conifer-hardwood stands.

Topography

All systems are most productive on flat areas, but where stands are located on short, steep slopes with rock outcrops, one generally avoids scheduling a Koehring operation. In practice, we use both wheeled skidders and Koehrings on such areas. Drott feller-bunchers are favored when topography, terrain and ground conditions are flat, soil conditions are better, and there are few surface boulders.

Coniferous-Hardwood Mix

Where only softwoods are to be cut, and the hardwood content is such that it interferes with Koehring mobility, the skidder system should be used. In practice, operators have challenged this rule and have operated in a mixture of poplar, white spruce (*Picea glauca* [Moench] Voss) and black spruce (*P. mariana* [Mill.] B.S.P.) with the Koehring system. They have obtained high productivity but have damaged a potential veneer poplar stand. Drott feller-bunchers should be assigned to mixtures containing less than 40% poplar.

Heavy Branchiness or Limby Wood

Koehring and John Deere systems work best since the machine limbs the trees and is ideal for these conditions.

Mixed Softwoods of Variable Diameter

In general these stands should be assigned to the skidders, depending on the need for separation of species or by-product material. In practice, the Koehring can operate in these stands and can cut butt diameters of 55 cm; however, shears, holding arms and tubes usually require extensive repairs as a result of damage caused by large, heavy white spruce limbs. Generally, there is a tradeoff with each system between the requirements for tree-length, 16-ft (approx. 5.3 m) logs, veneer and special materials such as poles and piling, and the cost of recovery.

Seasons of Year

To minimize rutting, heavy equipment systems should not be used in deep soils during the wet periods in May, June, September and October. Careful planning and pre-cut inspection will ensure that such stands or areas are logged in March and April when there is still frost in the ground. Where the balsam fir (*Abies balsamea* [L.] Mill.) component in softwood stands is high, we try to log as little as possible with Koehrings because balsam fir tears apart in the delimber cycle.

Operators harvest such balsam fir areas in March, April, November and December when frost assists in the removal of limbs. Most low-yield mixedwood stands with heavy underbrush are logged best by wheeled skidder systems in October, November, April and May before leaf-out period. Skidders usually make trails to the large white spruce for the manual fellers. We also minimize winter cutting of stud material stands with Koehrings because shear damage is higher in frozen wood.

Overmaturity

The age of a stand is important. Experience has shown that it is best to assign areas containing butt rot or windthrow to skidders, because these are most effective in minimizing cull wood. Where windthrow is excessive, we avoid using Koehrings because we find that we are left with a great deal of broken, dry merchantable material, and are forced to assign cutting crews to cleanup duty. The Koehring operators have a problem in discerning diameter in stands with 70% of their material in the 15-30 cm DBH range and the remaining 30% in the 7.5-12.5 cm range; there is invariably a great deal of waste.

Wildlife Habitat

Moose wintering areas can be logged with a wheeled skidder where the hardwood component is high. Operators leave small clumps of balsam fir or spruce for shelter. Eagle nesting areas present a problem, however, because logging must be restricted to areas some distance from the site of the nests.

Silviculture Policies

The new "red flag" designation of Protection Forest Reserves, a subjective estimate of soil depth which indicates a modified cut situation, can be handled by both Koehrings and skidders. On heavy underbrush or second growth, where yield per unit area and tree size are acceptable, the logger uses wheeled skidders to minimize damage; however, in practice, Koehrings can cut these areas during the dayshift and move to other areas with fewer restrictions for the nightshift.

Koehring garage sites in summer months are large, approx. 165 m x 65 m, and must be bulldozed to mineral soil to meet fire regulations; these areas should be rehabilitated when operations are completed.

Other Restrictions

a) On shoreline reservations adjacent to lakes the Ontario Ministry of Natural Resources (OMNR) stipulates that a 133 m reserve be left and that block cuts be made to the waterline by Koehrings one year, and by skidders the second year to prevent compaction.

b) Sections which have been set aside for lakeshore reserves and Protection Forest Reserves may include productive areas slated for future silvicultural treatment.

c) The multiple-use concept has been applied in the Northern Light Lake Plan, with certain areas designated for recreational use first and logging second; i.e., during July and August there must be no logging within 0.8 km and yet Koehrings can be heard for 8 km. Buffered portage trails and narrow roads, which are required by the plan constitute safety hazards. We are learning how to operate under such restrictions but we often question the wisdom of the people who draw up these plans.

I will now describe current harvesting practices, with special reference to ground conditions and species occurrence and their effect on the type of logging system allocation.

Current River: This area is located some 80 km north of our mill and just beneath the east arm of Dog Lake. The topography is rough to rugged on the highlands and grows a variable forest of mixedwood types, luxuriant shrubs and undergrowth, and single dominant coniferous types. Birch (*Betula* spp.) and black spruce are more dominant on till slopes and on top of lowland hills. The whole area has been subjected to severe burns; hence, poplar, white birch (*B. papyrifera* Marsh.) and pine flourish. Wide fluctuations in temperature throughout the year have an effect on the species composition of this area. A small contractor in the area produces approx. 104,000 cu. m of pulpwood and approx. 3,600 cu. m of tree-length by-products for us, mainly from upland sites containing 40% poplar and white birch and 60% black spruce, balsam fir and jack pine.

Black Sturgeon: This area is located 120 km north of the Thunder Bay mill and just southwest of Lake Nipigon. It has a low, rolling topography with diabase and some sedimentary rock forming rugged exposures. Most of the rock is buried under deep lake deposits, sands and morainic material on higher elevations. The forest stands are uniform with black spruce dominating most of the communities. The better drained soils support mixed stands of poplar, white birch, black spruce, white spruce and balsam fir, with white spruce and balsam fir achieving prominence on sites protected from recurring fires.

Dog River: This area is located 104 km northwest of the mill and just west of Dog Lake. It has a rough, rolling topography with some plateau features formed by strong glaciation. There are occasional morainic ridges, deep silted lacustrine flats, and sand plains. The soil is thin over granite rock. Fires have been frequent and have contributed to erosion in the uplands. Large areas are covered by coarse-textured soils over bedrock which have poor potential for forest production. Stands are usually black spruce and jack pine with mixtures of white spruce, balsam fir, poplar and white birch.

Mattawin: Of interest is our new Unit 517, 136 km west of the Thunder Bay mill in the Great Lakes-St. Lawrence forest region (Rowe 1972) next to Quetico Provincial Park. The soil and climate of this vast area favor the development of white pine and red pine (*Pinus resinosa* Ait.) communities. It is strongly glaciated with thin, coarse-textured soil deposits containing granites, sediments and volcanic rock of the Precambrian era. As a result of logging and fires, boreal species in pure or mixed stands of jack pine, poplar, white birch, balsam fir, black and white spruce have been introduced; all are variously associated with white pine, red pine, scattered yellow birch (*Betula alleghaniensis* Britt.), black ash (*Fraxinus nigra* Marsh.), white elm (*Ulmus americana* L.) and red maple (*Acer rubrum* L.).

In conclusion, I would like to make a few observations about stand renewal in mixedwood stands following harvesting.

Our inability in the past to use large volumes of oversized material in Black Sturgeon, Dog River and Mattawin--namely, white spruce on upland sites--has resulted in an overmature decadent forest with mixtures of white and black spruce, balsam fir, dead birch and scattered poplar. Balsam fir understories are unmerchantable and the yield per ha runs from 45 to 108 cu. m. Over the past three years, we have been using combinations of different logging systems to harvest such stands on a selective basis.

Many of the upland mixedwood sites, with heavy hardwood content, were never treated with scarification equipment because only selective cuts were made. Many of these areas have regenerated naturally to balsam fir, which will make up the next stand. As fibre costs increase with distance, operators will find an efficient way of utilizing this balsam fir which is so close to the mill.

Industry must join OMNR in treating these fertile sites. New forest management agreements will reflect this need in the next five years.

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CURRENT MANAGEMENT PRACTICES IN THE BOREAL MIXEDWOOD FOREST: NORTHEASTERN REGION

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Current management practices in the boreal mixedwood forest of the Northeastern Region are discussed in terms of management planning and silvicultural treatments. Forest management planning recognizes only species, working groups, and site classes based on age-height relationships and does not recognize the boreal mixedwoods as an entity. Management of even-aged stands using a clearcut system of harvesting is the norm. Past and present silvicultural activities are discussed. Recommendations based on experience are made for site preparation, planting, and tending operations.

Les techniques d'aménagement en cours dans la forêt du Nord-Est sont examinées sous le rapport de la planification de l'aménagement et des traitements sylvicoles. En planification de l'aménagement forestier, on ne reconnaît comme entités que les essences, les groupes fonctionnels et les classes de station fondées sur les relations entre l'âge et la hauteur des arbres, mais non la forêt boréale mélangée comme telle. L'aménagement des peuplements équiennes par la coupe à blanc constitue la norme. Les pratiques sylvicoles passées et présentes sont examinées. Des recommandations fondées sur l'expérience sont faites en vue de la préparation des stations, de la plantation et des soins culturaux.

INTRODUCTION

The Northeastern Region of the Ontario Ministry of Natural Resources (OMNR) spans the transition between the Great Lakes-St.Lawrence and the Boreal forest regions. Although we have pockets of both general forest types, the bulk of the region supports a forest of a transitional nature. Therefore, I will discuss management practices in the mixedwood portion of the transitional boreal forest, which very often includes such species as white pine (*Pinus strobus* L.), red pine (*P. resinosa* Ait.), and large-tooth aspen (*Populus grandidentata* Michx.) along with the usual boreal species. I will concentrate on management planning and silvicultural treatments in the Northeastern Region.

MANAGEMENT

Forest management, as practised in Ontario, is implemented through "Forest Management Plans". These plans are designed to outline the ways and means of manipulating the forests through harvesting and silvicultural treatments to provide continuing benefits to the people of Ontario.

Management plans were first established in Ontario in 1958. Some of the early plans were in fact not completed until the mid-1960s.

Staffing of the various units with professional foresters and qualified technicians has been a relatively recent innovation. The first unit foresters came to the area in the mid- to late 1950s. Not until very recently have we had a unit forester for each unit. Today, there is one forester per 3,900 sq. km of forest land in the Northeastern Region. We have scarcely enough manpower to tackle the problems of extensive forest management, let alone the intensive management required for the mixedwood forest.

We have, in total, about 25 years of experience behind us in the extensive management of the forest. If we consider that forest harvesting has been going on since the 1800s, we can very easily see why Professor Ken Armson (Armson 1976) stated that we are still in the "exploitation...administration...and regulation" phases of forestry and not into true management.

Our inventory and our management plans do not recognize "mixedwood" sites. All broad planning is carried out using working groups and Plonski's (1960, 1974) site classes. Species associations such as spruce-fir-aspen cannot be dealt with except on an individual stand basis.

Site, in terms of Plonski's (1960) definition of site class, consists of a height-age relationship which has no direct link with any ecological site unit. Site factors such as soil and topography are not considered in any detail in the planning stages of management. Thus, within the planning system the boreal mixedwood sites are not recognizable as an entity.

All boreal forest working groups in the region are managed under the even-age management system. Some form of clearcut silvicultural system is applied to all stands. The extent to which any given stand is clearcut in practice depends largely on the local market conditions for a given product.

Those stands which would be classed by participants in this symposium as boreal mixedwood pose a very real problem in the Northeastern Region. Markets for aspen (*Populus* spp.) and white birch (*Betula papyrifera* Marsh.) are very limited and localized. Pulpwood markets are concentrated in the southern portion of the region, primarily along Highway 17. At no time in the past have we had markets for all species and products available from the mixed stands. As a result, partial cuts have been the rule and not the exception. High-quality softwood such as white spruce (*Picea glauca* [Moench] Voss) and black spruce (*P. mariana* [Mill.] B.S.P.) and the pines (*Pinus* spp.), along with veneer-quality aspen and birch, have been cut out and the poor quality material is left standing.

In reaction to this "high grading" of the better materials and in the interest of better utilization and better silvicultural handling of these areas, several guidelines have been issued by OMNR's head office and our regional office. The following are guidelines for controlling cuts on allocated mixedwood stands:

"1. Stands where the softwood volume is less than 30% of total net merchantable volume of all species, based on operational cruise estimates and approved cull factors, will not be approved for cutting unless all the hardwood volumes are utilized at the same time.

2. Stands, where the softwood volume is more than 30% of the total net merchantable volume, may be approved for cutting at the discretion of the District Manager.

3. Stands requested for cutting, where the prime licensee will utilize some of the volume but not the total volume of the stand, and other markets exist in the area may not be approved for cutting by the District Manager unless the licensee agrees to clear-cut as prescribed, removing all species and products.

4. No single purpose, poplar veneer operations will be permitted in any previously uncut stands."

In our approach to the utilization problem it can be seen very clearly that we have in fact used administrative control to regulate the exploitation of mixedwoods, primarily as the result of an imperfect market situation. These controls are considered necessary, under the circumstances, in order to implement the basic system of clearcutting followed by the silvicultural activities of regeneration establishment and subsequent tending treatments.

SILVICULTURE

Our basic aim in the silvicultural systems we are using today in the mixedwoods is to try to maintain a softwood component at existing levels, wherever it is deemed to form an important commercially desirable product.

In the first 20 years of silvicultural activity in the Region, the objective quite often was that of stand conversion to conifers on the mixedwood sites. A typical prescription for an area which supported a stand with an aspen or white birch working group, growing on medium to poor sites, was that of total stand conversion to white spruce or some pine species. In most cases, conversion efforts were doomed to failure because of the profuse suckering and superior growth rates of the hardwoods. The use of 2,4-D herbicides was attempted but these herbicides were misused or poorly directed in the early field trials.

In a recent survey of all areas over 400 ha in size planted between 1955 and 1975, it was found that, without exception, these areas were on some form of fluvial sands and gravels and not on the typical mixedwood sites of the Region. This would indicate that silvicultural treatments in the tougher mixedwood sites had been bypassed. One reason for the lack of activity on these sites might be that harvesting in this period was probably restricted to the primarily pure softwood stands found on dry sands and gravels. On the dry sand flats relatively high volumes of desirable species could be extracted at minimal cost. A second reason could be that, because of the poor utilization and rougher conditions for planting found on the mixedwood sites, only few treatments were attempted, and for many of these, the records have been lost.

Our silvicultural experience on mixedwood sites is limited. Over time, we have learned some extremely valuable lessons. Our current practices are a direct result of the lessons we learned from our failures of the past.

REGENERATION ESTABLISHMENT

Within the Region, we use three broad categories of regeneration establishment. On sites which currently support a good stand of primarily aspen, at high site indices and where the utilization of all species is extremely good, we use what is termed "the unassisted natural regeneration" method. That is, we do absolutely nothing to establish or tend for regeneration, except carry out a stocking assessment survey after about five years. The next category is that of "the assisted natural regeneration" method in which we remove any residual forest cover and attempt to reduce the slash component. This method is used on good, high site class aspen stands which, because of a high residual or slash component, are not likely to sucker readily and produce a sufficient number of stems per unit area. The third category is that of "artificial regeneration" treatments which are carried out on the poorer hardwood sites with a high softwood component.

For the "assisted natural regeneration" method of regeneration establishment, our aim is simply to induce suckering so that we get the required 12,500 stems per ha. Our equipment consists of a tractor capable of knocking down residual trees, and a set of drags such as the shark-finned barrels. The drags break up and align the slash, so as to allow more solar radiation to reach the soil and thereby raise its surface temperature, and at the same time they damage the shallow aspen roots slightly in order to stimulate root suckering. The TTS disc trencher and a heavy 180 h.p. skidder have recently been used to perform the same function as the older and less efficient crawler tractors and barrel rigs.

The artificial re-establishment of conifers as stands which would normally revert primarily to hardwood stands of poplar and birch is an expensive and difficult task. Therefore, this method is used only where the utilization of all components of the existing stand is relatively complete, i.e., where all merchantable wood is removed, and where the site is marginal for good poplar growth. These tend to be either drier, gravelly or sandy loam sites, or imperfectly drained, moist, silty or clay soil sites. Intensive site preparation, planting and tending are essential for success.

PLANTING

Species selection plays an important part in the success of subsequent treatments. White spruce, which has been a common favorite in the past for mixedwood sites, has had variable success in our planting program. This species is extremely sensitive to late spring frost and poor soil aeration and should be used only on sites with good air drainage and well drained, loamy soils. Because it is shade tolerant, white spruce is a good species for the upper to middle slopes of the mixedwood sites.

White pine is another logical choice for the mixedwoods of the Northeastern Region. It grows well on the very well drained upper slopes in soils of practically all textures. Because it requires shade, it is an ideal component of the mixedwood forests.

For the more poorly drained soils or the sites with poor air drainage, either black spruce or one of the hard pines is recommended. Tamarack (*Larix laricina* [Du Roi] K. Koch) is an interesting alternative on these sites, but we have only begun to experiment with this species.

On sites on which we use black spruce or the hard pines, we aim for a high coniferous component for the mixed stands because these species have a relatively low tolerance for shade.

Balsam fir (*Abies balsamea* [L.] Mill.) is not considered a desirable species for the mixedwoods of the Northeastern Region and is never introduced on a site, nor are any artificial treatments used to promote the species.

PLANTING STOCK

Planting stock selected for use on mixedwood sites has to be able to grow rapidly after planting. We have had problems in this regard with all seedling bare-root stock, with the possible exception of jack pine (*Pinus banksiana* Lamb.). Black spruce and white spruce are well noted for their "check period" of three to four years. Red pine 3 + 0 stock has recently suffered from the "grey bud" or "silver bud" syndrome. The degree to which a tree grows after planting is largely a function of the physiological condition of the plant and its growing environment. We suspect that part of the blame for the poor performance of seedling stock attaches to its poor physiological condition at the time of transplanting. The transplant stock types, i.e., 1½ + 1½, 2 + 1 and 2 + 2, especially for spruces, are recommended for use in the planting program.

From casual observation of stock performance in the field and on the basis of some yet to be published results of container stock trials, there is growing evidence that a sufficiently sturdy container-grown seedling (700 mg oven-dry weight) will perform as well as or better than bare-root stock, even in highly competitive situations. The container seedling may become the choice of the future.

For hard pines (red pine and jack pine), 2 + 0 bare-root and container stock (paperpot - 408) are recommended. For white pine all stock types produced by the provincial nurseries are accepted.

SITE PREPARATION

Site preparation for planting is highly dependent on the condition of the stand after harvesting and the species to be planted.

Prescribed burns are used very effectively on mixedwood sites in the Wawa area to reduce the quantity of slash for more effective mechanical treatment. The burns are carried out primarily when the hazard index is low, i.e., in early spring. Elsewhere, summer burns have been attempted for the purpose of slash reduction and "duff" removal, i.e., complete one-step site preparation. It is thought that prescribed burns not only reduce slash and the depth of the humus layer but also eliminate balsam fir from these sites for the next rotation. The major drawback of prescribed burns as a site preparation method is that they are "seasonal". Our forest protection staff, who carry out these burns, permit very few burns during the high hazard periods of midsummer.

The bulk of the site preparation is carried out by mechanical and chemical means. Mixedwood sites which are rich in nutrients and have good moisture conditions require both chemical and mechanical treatment.

The most common chemical used to date is 2,4-D in its ester or amine form. It is applied primarily from the ground with a sprayer unit mounted on a heavy trailer. There have been few aerial applications in the Northeastern Region in recent years. The chemical 2,4-D is applied on areas which are not prone to heavy growth of grass. Its use on very fresh, fine textured soils such as silts and clays is not recommended. Often, brush and poplar appear within a few years. In one brief study it was found that after aerial application of 2,4-D-ester at 3.4 kg a.i. per ha up to 85% of the original competition had returned within about three years of spraying.

Experimentation with Roundup® (glyphosate) and Velpar® (hexazinone) is under way to control raspberries (*Rubus* spp.), maple (*Acer* spp.), various brush species and to some extent grasses. These chemicals have shown promise but are not yet in operational use mainly because of their cost and registration status.

Most mixedwood sites require both mechanical and chemical treatment. Where this is the case, we have found that mechanical treatment should precede chemical treatment. The recommended procedure is to prepare the site mechanically in late summer, fall or early spring following harvesting. The vegetation is allowed to respond to the mechanical treatment until midsummer, at which time the chemical is applied to kill the new suckers or seedlings. The area is then planted the following spring.

The tools for mechanical site preparation should be carefully chosen. Where pines are to be established by planting, the tool used most often today is the crawler tractor with a straight blade, a blade modified by Young teeth, or a blade rake. The basic objective is to remove the slash for ease of planting and to skim off the "duff" layer to expose mineral soil. The success of this operation depends largely on the tractor operator.

The TTS disc trencher is used extensively on areas with less slash. The advantages of the TTS over its blade counterpart are its low operating cost and its maneuverability.

On sites where white spruce or black spruce is to be planted, the use of a slash-clearing V-blade has proved successful. The objective of this treatment is simply to remove the slash component in a "corridor" fashion, leaving the humus layer intact. We have found that, for spruce, good root regeneration after planting and subsequent growth of the tree are highly dependent on the organic content of the upper layers of soil. Root development of spruce tends to occur at the "duff"-mineral soil interface either from adventitious roots or from existing roots placed in this zone. The V-blade with no cutting edge is a useful tool for ensuring that the humus layers of the soil are not overly disturbed. Mounding or inverting the top soil horizons has been attempted with a certain degree of success. For this purpose the Marttiini plow could be used, or even the TTS trencher, provided that the planting crews are well trained to select the proper microsite.

TENDING

The tending phases of silvicultural treatments cannot be ignored. Some form of release is required on most sites two or three years after planting. Failure to carry out release work results in plantation failure.

Tending in the mid-1960s using a chemical spray of 2,4-D was not too successful. Several red pine plantations suffered from heavy losses about 4 years after application of the ester form of 2,4-D. Shoestring root rot (*Armillaria mellea* [Vahl. ex Fr.] Kummer) was the responsible agent.

The aerial application of 2,4-D also had a tendency to kill poplar tops without killing the total tree, and as a result was ineffective as a release treatment. Another problem was the lack of a ground survey to determine how severely the competition was affecting the desired crop. Areas were sprayed in which the crop trees present were not under severe competitive stress, while some areas had no crop trees to release.

Today, most of the release operations are carried out by hand, with tools such as a brush hook for cleaning around crop trees to a radius of about 1 m. Only amine forms of 2,4-D are recommended for use when chemical release is contemplated, and are usually applied from the ground. Roundup® and Velpar® are being tested for this purpose and seem to offer an alternative to hand release.

PROBLEMS AND SOLUTIONS

Some of the problems associated with mixedwood sites are poor utilization, lack of precise site inventories, and our imperfect working knowledge of the mixedwood ecosystems.

In the Northeastern Region we are currently working on methods of estimating wood utilization and forest depletion. The mixedwoods are of major concern in this respect. The estimate of depletion or of forest drain is of paramount importance to the manager since it has a direct bearing on the annual allowable cut and the productivity of the forest. Where imperfect utilization does occur it is important to determine the extent of the drain and also the quality of the remaining wood. A good data base is essential for good decision making.

A broad forest land productivity survey is under way to quantify and document the extent of the land base suitable for forestry purposes in the Northeastern Region.

On the basis of the site specific-species specific yield curves which are being produced and the soil inventory, we should be able to determine the quantity of land suitable for mixedwood management and estimate the productive potential of that component. We should also be able to estimate to what extent one can manage on given sites.

Further work on stand dynamics, growth potential and ecosystem analysis of the mixedwood sites of the Northeastern Region is contemplated in the near future.

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CURRENT MANAGEMENT PRACTICES IN THE BOREAL MIXEDWOOD FOREST:

NORTH CENTRAL REGION

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A brief history of forest management practices in the mixedwood forest in the Geraldton District is given as an introduction to current management practices. Prescribed burning in summer is suggested as the best method of site preparation for these sites. The planting of black spruce nursery stock is the only feasible regeneration option on these sites, and should be followed by aerial spraying with herbicides. Some management practices that may be implemented in the 1980s in the mixedwood forest are also discussed.

Comme introduction aux pratiques actuelles d'aménagement, l'auteur a choisi de donner un bref historique des méthodes d'aménagement dans la forêt mélangée de la circonscription de Geraldton. Dans ces stations, le brûlage dirigé en été est suggéré comme étant la meilleure méthode de préparation de la station. La plantation de plants d'Épinette noire cultivés en pépinière est la seule façon de régénérer la forêt à ces endroits, et elle devrait être suivie d'un épandage aérien d'herbicides. Certaines techniques d'aménagement qui pourraient être appliquées au cours des années 80 sont aussi discutées.

INTRODUCTION

Mixedwood forest occupies the most productive sites in the boreal region. Approximately 25% of all forested land in the Geraldton District is classified as mixedwood. With the ever increasing demand for wood, more intense silvicultural management of this forest is essential. However, because of the varied and dynamic nature of mixedwood stands, the forest manager cannot set a uniform management plan. Rather he must make his management decisions according to local economic and site conditions. It would be presumptuous of me to say that our management of the mixedwood stands in the Geraldton District is fully satisfactory, but in the last few years our professional staff have become more aware of the importance of the mixedwood forest and, consequently, the level of management is steadily improving. In view of the vast areas involved and the growth potential of these sites, I believe that the mixedwood forest should be high on our list of priorities when we are considering future silvicultural and forest operations.

PAST PRACTICES

Management of the mixedwood forest in the Geraldton District began with the first planting of nursery stock by the Longlac Pulp and Paper Company in the 1950s. Foresters working for the company at that time believed that the cutover mixedwood stands were the most suitable for tree planting. Their opinion was later confirmed by studies carried out by Professors R.S. Hosie and A.S. Michell of the University of Toronto's Faculty of Forestry and many of the company's foresters. These studies were carried out on all cutover lands on the Longlac Pulp and Paper Company's limits with specific emphasis on three major factors: the presence of advanced and natural regeneration; growth potential of the site; and justification of the capital investment as well as the return on that investment.

The mixedwood cutovers proved most suitable on all three counts. Consequently, the company carried out a large percentage of its tree planting on the mixedwood sites (Table 1).

Table 1. Planting by the Longlac Pulp and Paper Company[a] on mixedwood sites, 1950-1972.

Stand type	Percentage of total area planted
Mixedwood	42
Jack pine - spruce	27
Spruce	20
Jack pine	9
Hardwood	2
	100%

[a] The company changed its corporate name to Kimberly-Clark Pulp and Paper Company Limited in 1957.

By 1955, the company nursery near Longlac was fully developed and a planting program of roughly one million transplant stock per year was established.

The tree planting program was established with the objective of supplementing the existing natural regeneration by planting 600 to 1,000 trees per ha. The natural succession following cutting on mixedwood types is to balsam fir (*Abies balsamea* [L.] Mill.) and trembling aspen (*Populus tremuloides* Michx.). The tolerance of balsam fir and abundance of poplar make the conversion of mixedwood sites to spruce (*Picea* spp.) almost impossible without extensive and costly site preparation. Therefore, the aim of the planting program was to increase the spruce component of the cutover mixedwood stand by planting amongst the established natural regeneration. This practice of planting persisted until the end of the 1960s and approximately 30,000 ha were treated in this manner. The change occurred in 1970 when site preparation programs were initiated to accommodate company planting.

Evaluation of this work was done on many different occasions and extensive discussions were held between 1968 and 1970. As a participant in these discussions and, consequently, in the decision to move to more intensive forest management, I was actively opposed to the Kimberly-Clark planting practices. However, after becoming thoroughly familiar with forest management in this area and following an extensive study of these plantations by the Ontario Ministry of Natural Resources (OMNR), I changed my opinion. I believe that the planting of skidways, skid trails and areas free from immediate competition, which resulted in fewer trees per ha, represented an extensive approach to silviculture which was in tune with the times. One should not forget that Kimberly-Clark bore the entire cost of this program until 1964 when the Crown assumed responsibility for reforestation in Ontario. The survey of these plantations has shown that black spruce (*P. mariana* [Mill.] B.S.P.) and white spruce (*P. glauca* [Moench] Voss) stocking was increased slightly (Fig. 1). Growth of the planted trees was in most cases better than or equal to that of natural spruce of the same age. The mixedwood forest in the Geraldton District was managed between 1950 and 1970 according to "the state of the art" and economic conditions of the time.

PRESENT PRACTICES

The Management Dilemma

Mixedwood stands in the Geraldton District are found on many different sites except where the soil is very wet or very dry. Species composition is extremely variable and most often changes with a slight increase in soil moisture, a decrease in soil depth, a change of slope or a change in fire and insect damage patterns. There are very few

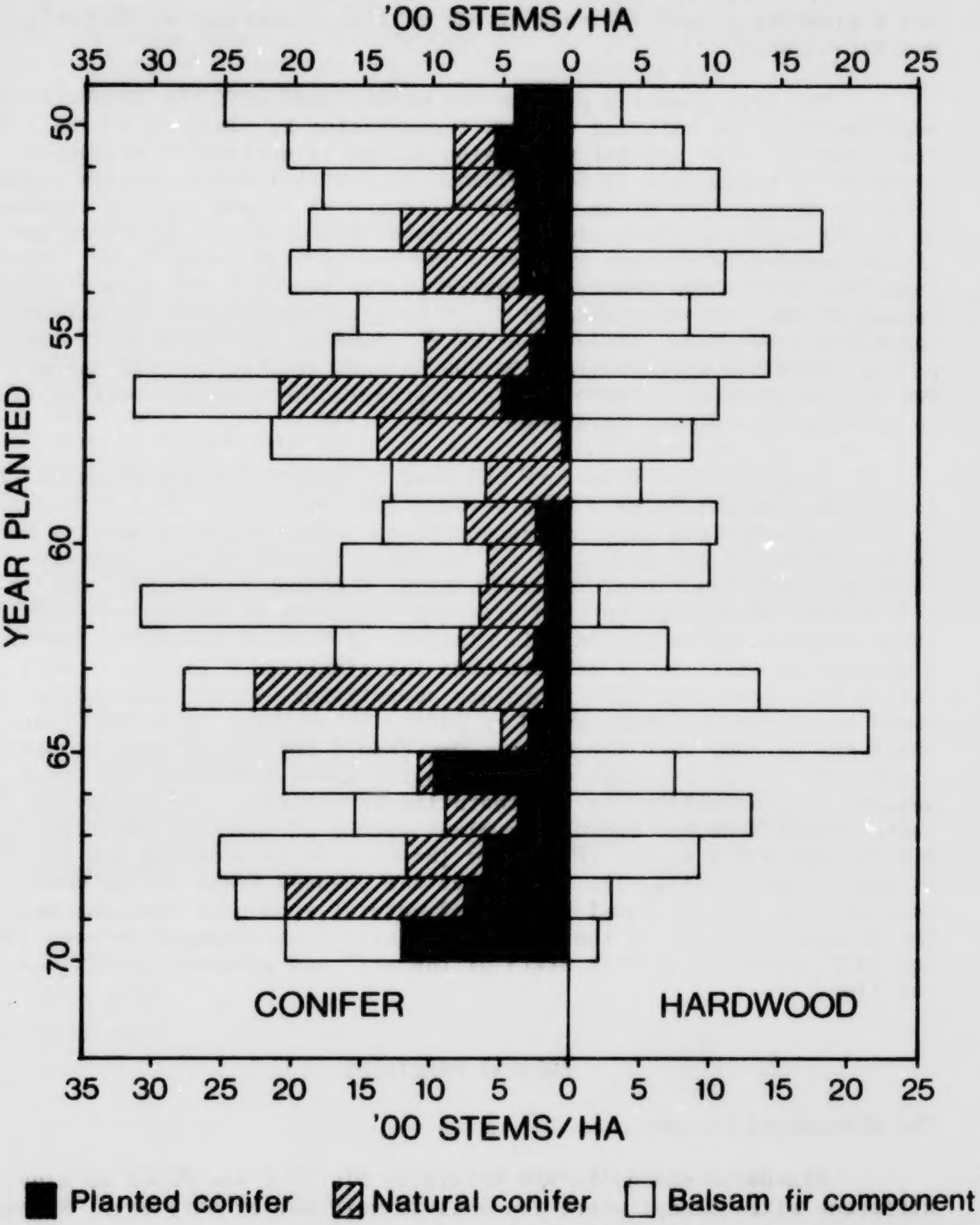

Figure 1. Average stems per hectare of planted conifer, natural conifer, and hardwood in each year of plantation establishment.

young mixedwood stands. Most are 80 to 120 years old and some very old stands (120+ years) in the outlying areas of the District are still being cut.

There is a tremendous variety in the internal arrangement of the species within the stand. The balsam fir could be part of the original stand but most often it forms an understory of varying degrees of thickness and height level. The brush species, such as alder (*Alnus* spp.), hazel (*Corylus* spp.), mountain maple (*Acer spicatum* Lam.), willow (*Salix* spp.), etc., are always present.

Current harvesting practices are compounding these complexities as they are guided by economic and market conditions rather than by any silvicultural considerations. All balsam fir under 10 cm in diameter are left standing. White birch (*Betula papyrifera* Marsh.) is not harvested at all and only approximately 50% of the poplar is removed. The resulting cutover looks like a warehouse for unwanted wood.

The only practical approach to classifying these cutover areas is to group them in very broad categories. We recognize four such categories of cutover mixedwood stands:

1. relatively clean cutovers where most of the poplar tree length has been removed
2. cutovers of overmature stands with patches of young balsam fir and old poplar trees standing
3. cutovers of mixedwood stands where white birch, the main component, was left standing (These cutovers may also contain balsam fir, aspen and brush.)
4. cutovers with high trembling aspen content which had not been harvested.

This categorization is simple and it is obvious that we are governed by "bush reality" rather than by Ministry guidelines and targets for the mixedwood stands.

Site Preparation

In my description of past practices, I indicated that an aggressive site preparation program was established in the early 1970s (Table 2). Now, as then, only two viable site preparation techniques can be used: mechanical site preparation and prescribed burning. Both techniques are slightly more advanced now than they used to be, but basically they remain the same. We started to scarify with chains and barrels, and the majority of mixedwood areas are still treated this way. Although the scarification drags and the machines pulling them have improved over the years, a relatively small percentage of the total area can be treated, mainly in categories 1 and 3. Topography and the presence of excessive slash and standing trees usually determine whether areas are or are not prescribed for mechanical site preparation. Where mechanical scarification was attempted in categories 2 and 4, area coverage was poor and quality and productivity were low.

Table 2. Site preparation of mixedwood cutovers in the Geraldton District.

Year	Cutover area (ha)	Area prepared by mechanical means (ha)	Prescribed burns (ha)
1970	2,558	26	550
1971	2,081	128	
1972	1,580	83	14
1973	2,313	216	
1974	2,238	200	
1975	2,640	307	412
1976	3,079	207	
1977	3,049	318	595
1978	3,648	494	426

A few very successful prescribed burns were carried out in the Geraldton District prior to 1970. On the basis of that experience we started to develop a site preparation program for all tree planting in the District. Within a few years we realized that prescribed burning is not a reliable treatment, because of bad fire years, staff and organizational changes, and weather conditions.

The combination of mechanical site preparation and prescribed burning eventually evolved as the standard treatment in the District. Almost all prescribed fires in the Geraldton District are used to prepare sites for planting. Although the prescribed burn prescriptions are specific for the site, the basic requirement is to remove slash up to 5 cm in diameter, small balsam fir, shrubs and other lesser vegetation. Site categories 1 and 3 are most commonly prescribed for this type of treatment. To achieve the desired results, it is necessary to burn during the summer months. The added advantage to this approach is that the duff layer is drier in the summer and the fire could burn deeper, thereby killing roots and reducing suckering. This was evident in several prescribed burns where aspen suckering was reduced for at least three years after treatment. All the standing trees are killed by fire and the shrubs, small balsam fir and ground vegetation are removed. Tree planters favor this technique on areas previously considered untreatable because it reduces the effort required to choose a microsite and physically plant a tree.

The ecological effects of prescribed burning are most often anticipated by prescribing the right treatment for the specific site. Coarse and fine sands are avoided entirely as hot summer burns completely remove the organic matter, creating very sterile conditions. Sites with rough topography are difficult to burn and erosion may become a problem. Shallow soils over bedrock are very common in our area. Hot summer fires can destroy the delicate nutrient balance between the organic layer and mineral soil and, if the organic layer is completely removed, the site could be damaged permanently.

However, in most areas in the Geraldton District where fires are prescribed, the danger of site damage is minimal. Deep and relatively fine soils are sought as a rule and the indices of fire intensity for a given fuel type are strictly controlled. There are many contradictory reports on nutrient release after a fire, but most state that there is an increase in soil nitrification and in other elements such as calcium, phosphorus and potassium. This is well demonstrated in the plantations established on these burns where tree growth is well above average.

Prescribed burning is an extremely useful site preparation technique and, if it is planned well in advance of cutting operations and executed according to site specific prescriptions, is the best technique for the mixedwood forest.

Regeneration Treatments

The first task that has to be undertaken when regeneration treatments are being considered is identification of the areas that already have sufficient natural regeneration. In the past this process was influenced by industry, which indicated to the silviculturist which species were required to run the mills. The assumption was always made that what was used today would also be required in the next rotation. Consequently, conversion to black spruce and white spruce was preferred by industry. But this traditional thinking is slowly changing. Stand conversions are very expensive and difficult to achieve. The utilization of trembling aspen is steadily increasing and the allowable cut will probably be fully utilized in the near future. As for white birch, it is just a question of time. Most of the cutting of trembling aspen takes place in the mixedwood stands in the Geraldton District. At present, approximately 1,000 ha are being cut annually for the Weldwood Complex in Longlac. These areas regenerate very rapidly with poplar suckers after cutting. To introduce conifer species on these sites is very difficult and expensive. Hence, poplar regeneration is accepted on these areas and is reported as satisfactory natural regeneration in our annual reports.

Balsam fir is the other species considered for natural regeneration. Balsam fir advance growth is present in all mixedwood cutovers, most notably in our categories 2 and 3. Though reluctantly accepted, the designation "balsam fir regeneration" is not as simple or as readily identifiable as is the designation "trembling aspen". Balsam fir advance growth may have been suppressed by the parent stand for many years or heavily damaged by logging equipment. Once released these stands could show remarkable growth, but at the same time they deteriorate very rapidly. Of course, if and when the spruce budworm (*Choristoneura fumiferana* [Clem.]) infestation spreads to the Geraldton District, balsam fir will be the budworm's main target.

In spite of these problems, approximately 1,200 ha are designated annually as regenerated to balsam fir. As I indicated earlier, this is "bush reality" and very little change will occur in the future on these areas unless utilization standards are improved.

The main regeneration method used today in the mixedwood forest in the Geraldton District is tree planting. Our annual program consists of approximately 2.3 million trees, of which two thirds are black spruce. In the past, white spruce was favored because of its tolerance to shade and its good growth and form. However, in the past five years, studies have shown that black spruce is performing just as well as white spruce and is resistant to budworm attack. Also, white spruce is more sensitive to root deformation as a result of planting.

In the Geraldton District we designate the most productive sites for tree planting. The process of elimination of areas is used to arrive at the best possible tree planting program. With prescribed burning, the manager can almost handpick the best site out of approximately 2,000 ha in categories 2 and 3. This approach, combined with good quality control in the tree planting projects, produced some excellent plantations.

I do not think it is necessary to dwell on the details of tree planting except to say that it is the major component of the silvicultural system in the mixedwood forest.

Most of the seeding techniques were tried in the mixedwood stands at one time or another and usually failed because of severe competition. The white spruce seed tree method was used quite successfully in a few areas in our District, but unfortunately mixedwood stands with an adequate number of seed trees per ha (minimum of 12) are very rare. If applicable, this method could be a more cost effective alternative to tree planting.

Tending

There are two basic methods in use for post-planting release in the Geraldton District: herbicide aerial spraying and hand release. Both methods have been used extensively on plantations established on the mixedwood cutovers. The effects of competition in tree plantations and the negative influence it can have on the growth of the conifer crop have long been recognized. Kimberly-Clark of Canada Limited was one of the pioneers in the aerial spraying of herbicides in northern Ontario. Thousands of hectares were sprayed for the release of plantations between 1954 and 1969. OMNR's present program consists of 800 to 1,200 ha of herbicide spraying and 120 to 200 ha of hand release per year, which roughly covers the total annual tree planting program. The tending program in the Geraldton District is part of the Provincial Implementation Schedule, which recognizes the fact that heavy investments in site preparation and tree planting have to be protected. Although some form of protection is necessary, I myself do not promote the use of aerial spraying. The cost effectiveness and smooth operation of aerial spraying cannot be denied. I object, however, to the haphazard nature of the treatment, especially in relation to trembling aspen. Quite often a poplar tree which is crowding and whipping a planted tree is not affected by the aerial spray and the young poplars that are not actively competing in the plantation are top-killed or badly damaged. I believe that our release techniques have to be selective in determining which members of the plant community and individuals should be removed from the system. These decisions should be made by trained foresters and technicians and should not be influenced by wind velocity, temperature and humidity and perhaps half a dozen other unknown factors. However, until a better method of herbicide application is developed, we are spraying 2,4-D with a fixed-wing aircraft at the usual rate of 2.25 kg a.i. per ha. In my opinion, it would be worthwhile to investigate old aerial herbicide spray areas to check the quality of the remaining trembling aspen.

The hand release method gives a forester complete control over which species and individuals should be removed from the plantation. Although this method is environmentally acceptable, the cost is prohibitive. Depending on the amount of competition in the plantation, it could range from $150 to $370 per ha which, in some cases, is more than the cost of the original regeneration treatment. The other problem is that very often it is necessary to repeat the release treatment at two- or three-year intervals, thereby making the whole operation uneconomical. In most of our early hand release projects, we used a well known technique in which poplar trees were just half cut and pushed to the ground. When inspections were done in some of these areas, it was discovered that most of the poplar resumed their normal growth except for an S-shaped crook where the cuts were made. Our new prescriptions will be calling for the complete cutting of trees as close to the ground as possible. It is hoped that with this new approach we can suppress competition for a longer period on our hand release plantations. Finally, I would like to suggest that the tending of plantations established in mixedwood stands has to be drastically improved. The goal described in the Forest Management Agreement as "free to grow" will not be attained unless target-specific, long-lasting and less expensive release techniques are developed.

FUTURE PRACTICES

The improvement of current management practices in the mixedwood forest in the Geraldton District has been given a high priority.

The 1977 study of old plantations in our District has shown that planted black spruce consistently outperformed natural spruce trees (Fig. 2 and 3). This reinforces the theory that tree planting is the best treatment for mixedwood sites. Therefore, I do not foresee any big changes in the District's tree planting program. There may be some limited mechanization, but basically our tree planting programs will remain similar to those in place today. Planting stock could be improved considerably through the use of greenhouses for the production of both bare-root and container stock.

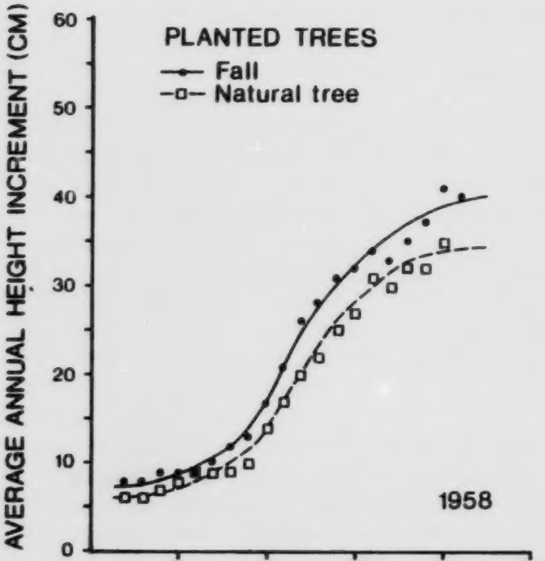

Figure 2. Average annual height increments of black spruce planted in 1958.

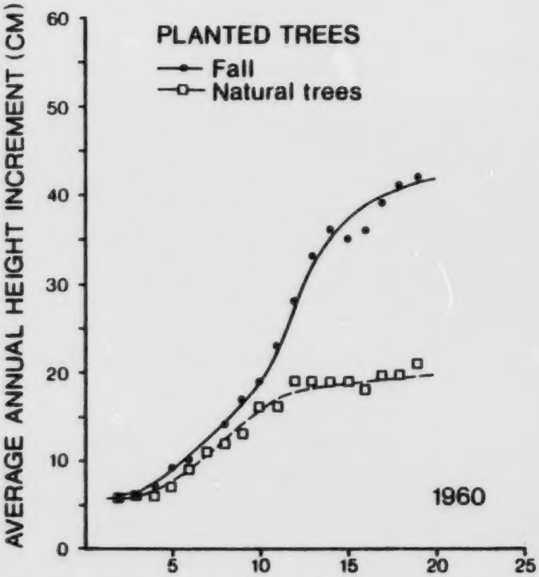

Figure 3. Average annual height increments of black spruce planted in 1960.

In my opinion, prescribed burning is the best site preparation technique for a mixedwood cutover and requires only operational improvement. The most obvious problem associated with site preparation is poor utilization of balsam fir and hardwood species. I am optimistic that utilization of these species will improve greatly because of expected high transportation costs in the 1980s. With improved utilization, most of our site preparation problems will disappear.

There are some very good pieces of scarification equipment on the market today. Some of these machines are already in use and some are still being tested. I would like to see more work done on adapting the age-old agricultural method of disking for use in forest management. The mixing of mineral soil and the organic layer, and the breakup of the root mat, could prove to be very beneficial for the establishment and growth of plantations.

I have already expressed my doubts about the effectiveness of our plantation release work. It appears to be most sensible to explore the ground application of herbicides, with emphasis on the operational problems. It is most probable that the Geraldton District will be doing the testing of ground spraying in the near future. Although this may prove to be a labor-intensive job, I still believe that a degree of cost effectiveness could be achieved.

Too often in the past, regeneration programs fluctuated in intensity in different areas of northern Ontario as a result of staff changes, reorganizations and the impatience of field people seeking quick results. The establishment of a good forest regeneration program takes years of dedicated work. If our foresters are not encouraged to stay on the management units for longer periods of time, these programs will fail, especially in a complex system like the mixedwood forest.

CURRENT MANAGEMENT PRACTICES
IN THE BOREAL MIXEDWOOD FOREST:
NORTHWESTERN REGION

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In the Northwestern Region we concentrate on management of even-aged stands, with special emphasis on maintaining the coniferous working groups. In spite of our efforts, there has been a conversion from spruce and jack pine working groups to hardwoods and balsam fir. Incomplete utilization of hardwoods is the most pressing problem in managing mixed stands.

Dans la région du Nord-Ouest, nous voyons surtout à aménager les peuplements équiennes, et plus particulièrement à maintenir les groupes fonctionnels de conifères. En dépit de nos efforts, on est passé des groupes fonctionnels d'Épinette et de Pin gris à des feuillus et au Sapin baumier. Le problème le plus pressant à régler dans l'aménagement des peuplements mélangés tient à l'exploitation incomplète des feuillus.

A part of the Northwestern Region is outside the boundary of the boreal forest. A small portion in the southwest corner is in the Great Lakes-St. Lawrence forest region, but for the purpose of this symposium, any of my remarks concerning the boreal mixedwood forest will refer to that small portion as well as to the rest of the region.

Current forest management practices in the Northwestern Region are not aimed at mixedwood management. In fact, there is no official recognition of a mixedwood working group as such. Management strategies are aimed at maintaining or increasing the permanent coniferous working groups and the upper site class of poplar (*Populus* spp.). The permanent coniferous working groups on which management emphasis is placed are the spruce working group, i.e., black spruce (*Picea mariana* [Mill.] B.S.P.) and white spruce (*P. glauca* [Moench] Voss) and the pine working group, i.e., jack pine (*Pinus banksiana* Lamb.) and, to a lesser extent, red pine (*P. resinosa* Ait.) and white pine (*P. strobus* L.). These management strategies are aimed at even-aged, single species management.

At this point, an explanation of "single species management" is in order. What is referred to here is the management system (i.e., harvesting pattern and various silvicultural techniques) geared to a particular working group (tree species). That is not to say that other "companion" species are unacceptable in the system. For example, in the jack pine working group, the spruces are acceptable companion species. White birch (*Betula papyrifera* Marsh.) and balsam fir (*Abies balsamea* [L.] Mill.) are not acceptable companion species and are considered useful only as nurse species. They are not expected to contribute to the final harvest crop.

So far, my remarks have dealt with general management strategies. Because there is no official recognition of boreal mixedwood stands, either in the inventory system or in the management guidelines of any of the approved management plans, no attempt is being made to maintain the character of these stands. Also, our recording system does not distinguish these stands from others which have the same working group, except by implication through site class designation.

Personal observation and estimates by unit foresters throughout the Northwestern Region indicate that the proportion of productive forest area which falls into the category of "boreal mixedwood forest" according to the definition adopted for this symposium varies from district to district, but over all is about 35%. Of this mixedwood forest area, approximately 35% is at present supporting relatively pure stands of conifers, of all species except balsam fir. In some areas the proportion is much higher or much lower. For example, in two management units in Red Lake District, conifers account for an estimated 80% and 90% of the area. By contrast, in the Rainy River Management Unit in Fort Frances District, there are no conifers except balsam fir. The stands in the Red Lake District are either pure jack pine or pure black spruce, or a mixture of the two. When these stands are cut, there is a very strong tendency for them to convert to conifer-hardwood mixtures or to hardwoods, particularly poplar. This tendency is evident in the stands we are trying to maintain in conifer working groups as well as in those we are not attempting to regenerate. There is general agreement among the unit foresters in the Northwestern Region that a large proportion of the present mixedwood or poplar stands at one time supported relatively pure conifer growth or at least contained a higher proportion of conifers than they do at present.

One example may serve to illustrate the situation. The Rainy River Management Unit in Fort Frances District has been exploited for timber since the 1870s. Sawmills in the early days, as now, depended primarily on coniferous species. Extensive agricultural settlement throughout the area testifies to the fact that these are good sites, certainly capable of supporting mixedwood forest as it has been defined for this symposium. Today, the conifer content is virtually gone from the area except in poorly drained lowlands or excessively drained shallow soils. The good forested sites support almost 100% poplar, with small amounts of balsam fir.

This trend is continuing. In spite of our efforts to maintain or increase the conifer working groups, more and more of the cutovers are converting to poplar, white birch and balsam fir. In 1978, an examination of 5-year-old cutovers throughout the Northwestern Region revealed that 26% of the jack pine working group and 10% of the spruce working group were lost to hardwoods or balsam fir on areas which were treated silviculturally to maintain the working group (Table 1). On untreated areas (Table 2) the losses of jack pine and spruce were 77% and 32%, respectively.

Table 1. Distribution of conifer and hardwood working groups on treated cutovers in the Northwestern Region.

	Working Group						
	Jack pine	Spruce	Balsam fir	Poplar ---- (ha) ----	White birch	Nonforested land	Total
Precut	2799	680	1	521	13	16	4030
Postcut	2068	613	42	1217	81	9	4030
Gains			+41	+696	+68		+805
Losses	-731(26%)	-67(10%)				-7	-805

Table 2. Distribution of conifer and hardwood working groups on untreated cutovers in the Northwestern Region.

	Working Group						
	Jack pine	Spruce	Balsam fir	Poplar ---- (ha) ----	White birch	Nonforested land	Total
Precut	3256	3164	1	1366	92	347	8226
Postcut	737	2151	1505	3522	295	16	8226
Gains			+1504	+2156	+203		+3863
Losses	-2519(77%)	-1013(32%)				-331	-3863

The harvesting system used in the Northwestern Region is clearcutting, or at least clearcutting of marketable material. In certain cases there are restrictions on the size of cuts or other variations of the system such as strip cutting, block cutting or patch cutting, but the basic system is clearcutting. This applies to mixedwood stands as well as to conifer or hardwood stands. Commonly, poplar and white birch are not marketable; either they are left standing or they are knocked over and left on the ground.

Incomplete utilization of the trees in a cutover area hinders subsequent regeneration treatment and establishment of the next stand. In mixed conifer-hardwood stands where removal of the conifers would leave a residual stand that would prevent subsequent regeneration treatment, the policy is to leave the entire stand uncut. However, where a residual stand would not prohibit subsequent regeneration treatment, removal of the conifer component of the stand is permitted. Generally, a 60% hardwood:40% conifer combination is considered the break-even point.

Although regeneration treatments can be undertaken in a residual hardwood stand, our options based on potential success are reduced. Also, the treatments which are open to us are much more difficult and costly to apply. We have found that the cost of mechanical site preparation with drag units doubles when physical obstacles such as standing or fallen trees are present. Furthermore, the degree of mineral soil exposure frequently is not as good. This poor mineral soil exposure, along with shading created by the residuals, usually precludes direct seeding as a regeneration treatment. Instead, underplanting, usually of transplant bare-root stock, is carried out.

The difference in regeneration cost between these two types of treatment is considerable. For aerial seeding, the cost of collecting and extracting the seed is less than $20 per ha. An additional $3.70 to $5 per ha for applying the seed brings the total price to about $25 per ha. For planting, the cost of collecting seed and producing nursery stock would be in the range of $150 to $300 per ha, respectively, for nursery stock or transplant stock. An additional $185 to $250 per ha for planting brings the cost to $335 to $550 per ha.

Additional problems are encountered on the richer sites in the form of competition from grass and sedges, poplar suckering, and other woody plants. Follow-up tending is almost always necessary to release planted conifer seedlings.

The foresters in the Northwestern Region were unanimous in stating that, in managing mixedwood stands, the first requirement is complete utilization of all species. Once this has been achieved there are a number of management options. Some of the questions we must ask ourselves are:

1. Should we be trying to maintain the coniferous forest with which we started out and upon which the forest industry in northern Ontario is based?

2. Should we instead accept whatever species occur, in whatever mixture nature provides them, with the expectation that fibre from all species will be in demand in the future?

3. Should a management system, e.g., the selection system, be adopted to accommodate mixed stands in which the species have different rotation ages?

Although these questions have yet to be answered, there is general agreement that the boreal forest is even-aged in nature and, from a biological point of view, must be managed as such.

In addition, the mechanized logging systems designed for harvesting even-aged stands, geared to clearcutting, and producing mainly pulpwood do not fit into a selection system of mixedwood management.

FOREST MANAGEMENT AND RESEARCH NEEDS IN THE BOREAL MIXEDWOOD FOREST OF ONTARIO: A PROBLEM ANALYSIS SUMMARY

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Forest management and research needs for the boreal mixedwood forest, *as expressed by forest managers and researchers, are presented in synoptic form under the following headings: data base needs, harvesting, forest renewal, tending and protection.*

Les besoins de l'aménagement et de la recherche forestière pour la forêt boréale mélangée *exprimés par les chercheurs et les aménagistes sont groupés en forme synoptique sous les rubriques suivantes: besoins de bases de données, exploitation, régénération des forêts, soins culturaux et protection des forêts.*

INTRODUCTION

Many statements made at various conferences, particularly the March, 1976 Ontario Ministry of Natural Resources (OMNR) conference on regeneration, regarding the lack of information applicable to the management of mixedwood stands, prompted the Canada-Ontario Joint Forestry Research Committee (COJFRC) request to the Spruce-Fir-Aspen Forest Research Committee for the preparation of a report expressing management and research needs in Ontario's spruce (*Picea* spp.)-fir (*Abies* spp.)-aspen (*Populus* spp.) [birch (*Betula* spp.)] forest.

The Spruce-Fir-Aspen Forest Research Committee was established by COJFRC in December, 1974. One of the Committee's terms of reference was "to promote improvement in the management of spruce-fir-aspen forest resources". The Committee's membership was composed of research staff of OMNR's Northern Forest Research Unit (NFRU) at Thunder Bay, and research staff assigned to the Management of Spruce-Fir-Intolerant Hardwoods project of the Canadian Forestry Service's (CFS) Great Lakes Forest Research Centre (GLFRC) at Sault Ste. Marie. The Committee preparing the report entitled "Forest Management and Research Needs in the Boreal Mixedwood Forest of Ontario" consisted of N.F. Lyon, Chairman (NFRU), J.T. Basham (GLFRC), A. Lehela (NFRU), K.M. McClain (NFRU), D.H. Weingartner (NFRU), and R.D. Whitney (GLFRC).

To prepare the report the Committee requested submissions of needs from both forest management and forest research units associated with this forest. These included the 32 OMNR administrative districts and regional offices in northern Ontario, four pertinent sections of the Forest Resources Branch, OMNR main office, eight units of OMNR's Ontario Forest Research Centre, 20 research scientists at GLFRC, and the members of the Spruce-Fir-Aspen Forest Research Committee. Submissions were received from 15 OMNR field offices, two OMNR main office units, two Ontario Forest Research Centre units, and one GLFRC research scientist, exclusive of input by committee members.

The submissions expressed a wide variety of opinions about the most pressing needs because of variation in the *boreal mixedwood forest*, levels of utilization, market availability, the low levels or lack of specific management policy, and current pest problems. Between 35 and 40 different management problems were identified in the submissions. The most frequently raised issues were poor utilization, lack of markets, conversion of mixedwood stands, the presence of residual hardwoods and balsam fir (*Abies balsamea* [L.] Mill.), site-species-productivity relationships, and pests. In the outline for the report the Committee included the problems expressed in the submissions, as well as additional items which it felt would become problems in the future management of the *boreal mixedwood forest*.

The report was organized in a manner similar to the process of managing a forest. It has five main sections: 1) data base needs, 2) harvesting, 3) forest renewal, 4) tending, and 5) protection, prefaced by a definition, description, and delineation of the *boreal mixedwood forest* of Ontario. Although the Committee was considering only the *boreal mixedwood forest* of Ontario, many of the points included may be applicable to other forests or working groups as well. Additional forest uses (i.e., for wildlife management, recreation and aesthetics) were intentionally not mentioned in order to maintain the project at a reasonable size. However, the Committee believes that when the *boreal mixedwood forest* is properly managed for wood and fibre production, its suitability for other uses will also be enhanced.

The main objective of the report was to stimulate increased interest in forest management and an awareness of the complexity and importance of the *boreal mixedwood forest* of Ontario. A secondary objective was the production of a problem analysis that could be used by OMNR's head office and by the CFS in considering past, present and future management and research in this complex forest.

SUMMARY OF THE REPORT

Data Base Needs

a) Provincial Level

The main emphasis in this subsection is on the development and acceptance of a forest management philosophy that includes specific mixedwood management objectives. The development of such a philosophy has been neglected because of an industrial preference for coniferous species that occur in pure or nearly pure stands, and the absence of a working definition of the *boreal mixedwood forest*.

The needs associated with the development and implementation of such a management philosophy as expressed in the submissions include: a provincially coordinated effort to locate or develop new uses and markets for the currently underutilized species; a supplemented Forest Resources Inventory that considers a mixedwood philosophy for definition and planning; an information system for obtaining growth, yield, and stand dynamics data; refined stocking standards that consider performance of natural and artificially regenerated stands; and a site classification survey to amalgamate silvicultural practice with growth and yield studies.

b) Local Level

To formulate and implement forest management policy decisions specific knowledge is required in at least three critical areas: autecology, synecology and forest land base. Under the present extensive management system, current knowledge in these areas is satisfactory; however, intensified management, resulting from increased market demand and diminished supply, requires in-depth knowledge and understanding in these areas.

The requirements as outlined in the report include: an increase in quantitative silvical information; definition of species-specific site requirements; definition of growth and yield by species for the variety of site and stand conditions encountered; an increase in stand dynamics information; and documentation of insect and disease associations and their impact on second-growth stands.

Harvesting

High grading for selected species or stems is the typical method of harvest in the *boreal mixedwood forest*; however, clearcutting of all species, except birch, does occur in some cases. The result of high grading is a residual stand that is wasted and physically hinders regeneration efforts.

The expressed needs under the general heading of harvesting included: a determination of the economic loss resulting from underutilization; development of new uses and markets for underutilized species;

determination of the impact of harvesting machinery and practices on site quality; evaluation of the potential of uneven-aged management; and evaluation of the impact of cutover size on stand dynamics and overall forest productivity.

Forest Renewal

a) Unassisted Natural Regeneration

Three of the main *boreal mixedwood forest* species regenerate naturally with little difficulty: aspen, balsam fir (*Abies balsamea* [L.] Mill.) and white birch (*Betula papyrifera* Marsh.). Because of increasing regeneration costs, predicted fibre requirements and managerial uncertainty about the acceptability of this "free" regeneration, there is a need for economic and silvical information on the species and the extent of this natural process.

Recommendations appearing in the analysis include: the development of a survey to determine the extent of natural regeneration; an economic evaluation of the importance of natural regeneration; and the development of control techniques where necessary.

b) Assisted Natural Regeneration

The increasing costs and limited success of artificial regeneration dictate that alternative regeneration methods be developed for spruce. Where aspen is an acceptable species, assisted aspen regeneration may also be warranted.

In the analysis, assisted spruce regeneration focuses on modified harvest cutting, specifically the white spruce (*Picea glauca* [Moench] Voss) seed tree system. Areas requiring clarification or development include: treatment cost, number and quality of seed trees, gene pool maintenance, seed year prediction, artificial flower induction, and site preparation methods and equipment. For aspen, the expressed need is for an evaluation of site preparation that considers the effects of intensity, timing, and method on the growth, stocking, and pathological quality of the induced regeneration.

c) Artificial Regeneration

Artificial regeneration in the *boreal mixedwood forest* presents a tough challenge to the management forester because of the vigorous competition on these fertile sites, or the presence of a residual stand following high grading or natural catastrophe. In view of the difficulty experienced with this regeneration option, efforts must be directed toward improving the level of return on the investment.

The primary concern identified in this section is the need for an economic evaluation of the three regeneration options (e.g. natural, assisted, and artificial regeneration) that considers the resulting species composition as well as growth and yield in light of the predicted market demand. Submissions dealing directly with the techniques of artificial regeneration addressed the following topics: the development of mechanical site preparation techniques for seeding and planting which take into account the control of competition, effects on stock performance, and effects on site quality; the effects of prescribed burning, as a site preparation technique, on site quality; the development of guidelines for the application of prescribed burning; the development of hand and mechanical planting techniques that are biologically acceptable for various types of planting stock and site conditions; the development of a "planting hazard index" to aid in the selection of species and stock type; an evaluation of the susceptibility of monoculture plantations to insects and diseases and the importance of genetic diversity; a definition of stock quality in terms of physiology and morphology; an evaluation of the use of mycorrhizal fungi as a biological stock improvement technique; an evaluation of various types of planting stock to promote the concept of continuous planting; and an evaluation of the importance of restricting seed collection to mixedwood sites.

Tending

a) Release and Thinning

In an intensively managed stand, release and thinning treatments are applied to maintain or improve the growth of crop trees, reduce rotation length, and increase yield and economic return. To date, release techniques have been confined mainly to hand and chemical methods; mechanical release and thinning techniques have not been widely applied.

The thinning and release aspects of tending emphasize the following: autecology - specifically the need for and degree of release or thinning, and an evaluation of the growth process following treatment; herbicides - environmental impact, rating of effectiveness, effects on secondary crop species, successional changes, effects on the spread of *Armillaria mellea*, and the development of guidelines for herbicide use; general aspects - economic impact of treatment, the development of standards, mechanization, and disease implications.

b) Fertilization

The probable benefits of fertilization are increased volume production and maintenance of site productivity. Before fertilization of mixedwood stands is considered as an operational treatment, an evaluation of the biological and economic returns in terms of stand age, site, species composition, and the species-associated growth response is required.

Forest Protection

a) Spruce Budworm

During the preparation and review of the report it was learned that a CFS task force on spruce budworm research in eastern Canada was in the process of preparing a similar problem analysis. It was therefore decided that no recommendations would be made for this subject area.

b) Other Insects and Diseases

In the development of the forest, the greatest wood loss caused by endemic insects and diseases is probably in the form of reduced increment. Documentation of damage in the old-growth forest, particularly damage by disease organisms, is available; however, documentation of damage in second-growth stands is limited.

Subject areas identified in the report as requiring further documentation or research are: the economic impact of insects and diseases; disease cycles as related to site, growth rate, and tree age; the occurrence and impact of *Armillaria mellea* on conifers; utilization of decayed wood; interclonal variation as a basis for aspen management; and trunk rot as a factor in setting the rotation length for balsam fir.

EPILOGUE

The foregoing summary includes most of the points covered in the report presented to COJFRC at its meeting on 24 May, 1979. The members of COJFRC accepted the report, but requested that the recommendations be priorized. The Committee declined to do so as it believed that this was a forest management responsibility. Mr. W.K. Fullerton, Director, Forest Resources Branch, OMNR, agreed. He accepted the responsibility, and appointed a committee under the chairmanship of Mr. G. Brown, OMNR, Northwestern Region, to priorize the recommendations.

Discussion

L.E. Skinkle: Mr. Jovic, you said that your spruce plantations could compete with poplar coming in and shortly thereafter you indicated that you carry out an aerial spray program with herbicides. Could you give me some explanation of the apparent contradiction?

D. Jovic: I didn't have time to cover that subject properly. Usually if you plant in an area that has been site prepared mechanically you have to be there within a year or two with some kind of tending. With prescribed burning, at least in our experience, it's a bit different. Poplar doesn't grow as thick or as fast on burned areas as on others. We suspect that the hot summer fire damages the parent root system. Eventually the poplar comes in and in the particular area I was talking about (burned and planted in 1970) we eventually got around to spraying it in 1979. So for 9 years it didn't really require any tending, but once poplar gets going it outperforms spruce, and we felt it would be a good idea to spray it.

J. Nolan: Mr. Jovic, with respect to your Table 1, in the column headed "Stand type areas", you indicated that 42% of the cutovers in the Geraldton District are in the mixedwood type. I take it that mixedwood pertains to original forest cover prior to cutting?

D. Jovic: No, John, the table just indicated the portion of the cover type that was planted. If you are asking what portion of the total productive area in Geraldton is in mixedwood, it's 25%.

J. Nolan: Okay, but mixedwood was the original cover type prior to cutting in the areas that were being planted. The second question is to Al Wainwright. Al, in your submission you mentioned, I think, that 50% of the poplar, none of the birch, and all of the balsam are being used in accordance with the Crown Timber Act. In your slide presentation I saw various levels of integrated management, so to speak, where some birch and poplar were used for veneer, some birch was used for fuel wood, etc. Roughly, what percentage of the mixedwood stands being operated are approaching complete utilization, and what do you think the percentage will be 10 to 20 years from now? Or is that a loaded question?

A. Wainwright: Well, to be brief, few of these stands are completely utilized. I tried to show that we are not utilizing all of them and we are allowing other wood users into them to get the birch, especially in the Black Sturgeon Lake area. There are areas in the Dog River working circle also where Laidlaw is involved. We have another little mill at Kakabeka and we have small contractors supplying birch there. There are many, many areas of poplar, heavy boreal stands where these operations do very poorly, but I say we can't bypass these anymore. We are going to have to get into them, especially in the Nipigon area, during the period covered by the next 20-year management plan. There's going to be a forest management agreement; we'll have to build many more roads to open up areas so that we can have the freedom of movement we need. Many smaller wood users will follow us in there.

T. Armstrong: Mr. Wainwright, you made a brief reference to shoreline reservations. Were you advocating selective harvest within shoreline reserves?

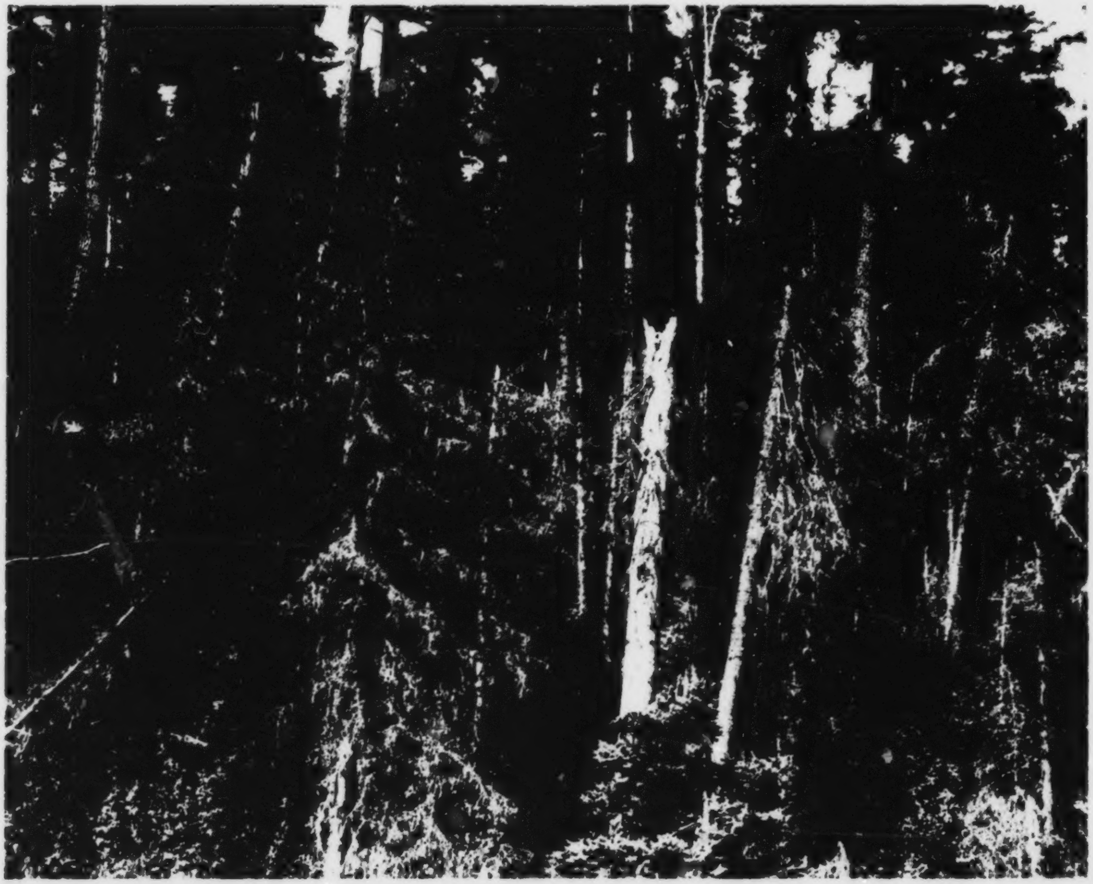
A. Wainwright: I believe that shoreline reserves are smoke screens for clearcutting, and I'd rather tell the public what is really going on. A tree can grow, and can be used and replaced. I'd far rather do some kind of block cut or strip cut in these areas, and still recognize the multiple use concept of the land.

M.A. Opper: I'd like to direct a question to Mr. Heikurinen. You were talking about restrictions in terms of the utilization factor, and you quoted a 30% conifer component--I've heard 40% mentioned, too. Is this OMNR policy or is it a ball park estimate for your region? Can you justify this figure of 30%? My second question concerns the allowable cut factor. Inasmuch as there are, or appear to be, restrictions placed on utilization of these stands, what kind of fiddle factors are you putting into your allowable cut, or have you taken that factor into account?

J.K.K. Heikurinen: The first question is easy to answer. There is an OMNR regional memo to the districts citing the 30% figure and I understand this came from a guideline that Toronto sent to the regions. It's a guideline, not a policy, and we have to have a certain amount of flexibility, of course. The second question is a rather tough one. There really can be no fudge factors in the allowable cut. Allowable cut is based on what there is, and if we set restrictions it's simply to make our job a little easier, I suppose, and to try and prevent waste of the wood that would be left--maybe 70%. Now there is an alternative to this procedure which is being used elsewhere, and perhaps it's used even in those stands that have over 30% conifer. When a company goes into a stand and harvests only 40%, the remaining timber, if it isn't harvested before it falls down, is then charged against the volume on that allowable cut. In essence it's depleted whether it's harvested or not, simply because it falls apart. I know in one area our policy has been that if one company (the licencee) hasn't harvested it all, and we have to send in a jobber to clean it up, then we charge that jobber's volume against the commitment to the company because we don't use a fudge factor in that case.

A. Wainwright: I might add something for Mr. Nolan who asked me a question on utilization. B Kraft mills can be completely converted to poplar and we have been looking forward to this now for the last four years, but nothing has happened. We are running a batch of this through in the next two months--we hope; it will be about 8,000 cords. We need to run through at least 200,000 cords of poplar just to clean up some of the old messes we have.

SESSION VI: FOREST MANAGEMENT CONCERNS: CONTROL OF VEGETATION



Spruce budworm killed balsam fir, Ranger Lake, Ontario.

SESSION VI: FOREST MANAGEMENT CONCERNS: CONTROL OF VEGETATION

Introduction (*J.R. Carrow*)

At last week's Constitutional Conference, the First Ministers did an admirable job of dealing with a very complex problem. With the expertise they gained in achieving consensus, I think we should turn the management of the boreal mixedwood forest over to them, because they are more likely to reach an agreement than we are. The importance of a lack of consensus becomes very evident in the theme of this session, which deals with control of vegetation and control of pests. Two species--aspen and balsam fir--play a central role in both these concerns. This is where a consensus is vitally needed and yet is lacking. More accurately, what is lacking is "management" as in forest management, because implicit in management is decision-making. We're not making the decisions we need to make with respect to aspen and balsam fir--tough though they may be--and therefore we're not managing. So perhaps that is the major forest management problem in the boreal mixedwood forest: we're not making decisions about whether to promote or discourage aspen and/or balsam fir regeneration. The consequences of that indecision are evident as we struggle with important problems such as regenerating cutovers and burns, managing spruce budworm and managing stem decay and root rot.

As you will learn during this session, the volume of fibre lost to decay, rot and spruce budworm is enormous and a large portion of that loss is in balsam and aspen. In the past we have accepted these losses, but with local wood shortages developing in many regions, the days of accepting such large losses are numbered. We must therefore decide whether to promote these species in certain situations and on certain sites, or to discourage them so that they will not constitute a major portion of the growing stock on which future wood supplies will depend. If we decide to promote balsam, that decision carries with it the responsibility for protection spraying against spruce budworm. If we promote aspen then we are faced with similar potential pest problems and the difficulties associated with short rotation management.

When I surrender the podium to the speakers I think you will be interested to note the central role that aspen and balsam fir play in each presentation. In fact, if these two species were not part of the boreal mixedwood forest, I doubt if Session VI would have been necessary.

Part I: Control of Vegetation

Phenoxy herbicides have been used in Ontario's forests for nearly 30 years, but information on the post-treatment performance of crop trees is very limited. Recent assessments indicate that balsam fir responds well to chemical release. On some sites (sandy and silt loam), volume production in released balsam stands exceeded that in unsprayed areas by 153-165%, 5 years after release. This benefit continued up to 20 years after treatment with increases in volume ranging from 200% to 260% on silt loam. Similar but less pronounced responses were observed for height growth, with increased growth of 50% to 75% over a 20-year period. The limited data available for spruce indicate that chemical release is much less beneficial to the crop tree.

Recent field trials have been conducted to find alternatives to 2,4,5-T. Glyphosate at dosages greater than 1 kg, a.i./ha has good potential for control of grasses, raspberry and poplar. Velpar® at dosages greater than 2.2 kg a.i./ha appears highly effective for grass control and moderately effective for raspberry control.

To improve the efficiency of herbicide use for forest vegetation control, research efforts should be directed to problems such as timing of application in relation to stand age, season and site; the cost-benefit ratio in the growth response of crop species; raspberry control; and long-term secondary effects; e,g., on plant succession, quality of crop trees, and incidence of root rot.

Special situations arise in which non-chemical tending is preferable to the use of herbicides. To date, most non-chemical tending (cleaning or liberation cuttings) has been used to release young spruce stands. The major limitations are quality of staff and equipment. Competent crew leaders are essential to ensure satisfactory results. Although Sandvic brush axes have been the standard cleaning tool, recent trials indicate that Husqvarna brush clearing saws may give increased productivity and a better overall result. Non-chemical tending may become more common in situations where there is concern about the effect of herbicides on non-target components of the forest environment.

Part II: Control of Pests

Of the three main agents which deplete the boreal mixedwood forest (fire, insects and diseases), *stem decay* emerges as the single most devastating factor. Estimates are that stem decay results in an annual loss of 5 million cubic metres of fibre in Ontario. In the boreal mixedwood forest, balsam fir and aspen are most seriously affected. The extensive spruce budworm outbreak aggravates the situation in balsam fir because of the widespread mortality of balsam. Standing dead balsam may develop sap rot one year after death. In live balsam, the increasing occurrence of stem decay as the tree matures makes harvesting of stands older than 70 years economically hazardous. At 100 years of age, about 20% of the merchantable stand is lost to stem decay.

At 100 years of age, the merchantable volume of aspen contains about 25% stem decay. Aspen suckers which survive scarification treatment are often severely wounded in the process and are much more susceptible to stem decay. Both white spruce and black spruce are relatively free of stem decay, with white spruce experiencing about 3% decay at 100 years and black spruce about 3.5% decay between 121 and 140 years.

Root rot tends to create problems in young stands (less than 30 years) or in older stands. In younger stands, mortality caused by *Armillaria mellea* is the most important single factor. This pathogen is widespread in the boreal mixedwood forest but mortality tends to occur in patches. In older stands, root rot causes premature windfall, butt cull, growth reduction, and mortality of standing trees. Balsam fir and black spruce are most seriously affected, with losses in 70-year-old stands of 33% of the volume of dominant/codominant trees. In white spruce, comparable losses are somewhat less (20%). These losses increase sharply beyond 70 years of age. Generally losses are higher on fresh to dry sites than on moist to wet sites.

To reduce losses to root rot, harvestable spruce and fir on susceptible sites (fresh to dry and coarse-textured) should be harvested before stands on less susceptible sites. Stands with a preponderance of balsam fir should be harvested first and those in which white spruce predominates should be harvested last.

Some other diseases of the boreal mixedwood forest are worthy of attention. Hypoxylon canker is a major problem, and in effect limits aspen culture to short rotations. Similarly, birch dieback persists as a major factor limiting the rotation period of birch. Aspen shoot blight can produce extremely high mortality of terminals in aspen under 5 metres high.

After stem decay, the spruce budworm causes the greatest annual volume loss in the boreal mixedwood forest, both from mortality and from reduced growth. Stands in which balsam fir and white spruce predominate are highly susceptible to budworm outbreaks and eventual losses in the form of reduced growth and mortality.

Top killing of balsam fir usually occurs after 3-4 years of feeding on the current growth, and mortality begins after about 5 years. White spruce and black spruce growing in mixture with balsam fir are less susceptible, but mortality begins to appear after 6-8 years of severe feeding. Volume losses in the current outbreak in northeastern Ontario are estimated to exceed 20 million cunits, representing mortality and growth reduction in balsam fir and spruce.

The spruce budworm, and an associated species, the spruce coneworm, are becoming increasingly important in seed production, because of the devastating effect these insects have on flowering and cone production.

BENEFITS OF HERBICIDE CONTROL OF UNWANTED VEGETATION IN THE BOREAL MIXEDWOOD FOREST

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On sandy, clay and silt loam sites, average heights of balsam fir were 47%, 19% and 51% greater, respectively, five years after herbicide spraying than they were in the unsprayed control area. By the 15th and 20th years, on silt loam sites, trees in the sprayed area were respectively 74% and 66% taller than those in unsprayed stands. The response for spruce was considerably less than that for balsam fir.

Cinq ans après un épandage d'herbicides, la hauteur moyenne du Sapin baumier croissant sur du loam sablonneux, argileux et limoneux était respectivement supérieure de 47, 19 et 51% à celle des témoins. Dans les stations de loam limoneux, les arbres traités étaient plus grands de 74% après 15 ans et de 66% après 20 ans que ceux des peuplements témoins. L'effet du traitement a été considérablement moindre sur l'Épinette que sur le Sapin baumier.

INTRODUCTION

Herbicides have been used in forestry operations in Ontario for almost 30 years. To date, however, little published or unpublished information is available on the performance of desirable vegetation subsequent to spraying (Miller 1958, Anon. 1964, Hughes 1967, Day et al. 1968, Jaciw 1972, Day 1974, Bunce 1979); much of the literature tends to emphasize effects of herbicides on target or unwanted vegetation (Skaptason 1953, Rudolph and Watt 1956, Helegeson 1957, Klingman 1961, Anon. 1979). This paper summarizes current knowledge of the major herbicides that have been, are being, or will be used shortly in Ontario. Included are 2,4-D, 2,4,5-T, glyphosate (Roundup®) and Velpar®.

HERBICIDE PROBLEMS NEEDING SOLUTIONS

Weeds are unwanted plants. According to Day et al. (1968) plants are weeds only in terms of our attitude toward them. They are weeds when they interfere with the utilization of land and water resources or otherwise adversely affect human welfare. Usually, this means that weeds are growing where we want other plants to grow or where we want no plants at all. On cropland and ranges, and in pastures and forests, weeds compete with more beneficial vegetation, reducing the yield and quality of produce. For example, Wilde et al. (1968) reported that weeds annually rob 47,601,840 kg of water from each hectare of red pine (*Pinus resinosa* Ait.) plantations on uncultivated soils.

To assist with the herbicide assessment program being developed by OMNR's Pest Control Section, some of Ontario's forest managers posed a number of questions about weeds to which they wanted answers. The questions were placed in the following order of priority in April, 1979:

1. During which season, and how many years after plantation establishment, should competition be sprayed? Does the timing vary with site type? When and where is a second spray generally required? Are there differences between naturally and artificially regenerated areas?

2. What is the quantitative growth and survival response in relation to degree of suppression by site type? Does amount of response justify the cost?

3. What is the plant succession after spraying? How seriously do the changes in plant succession affect growth and survival of crop trees?

4. How do we kill raspberries (*Rubus* spp.) with 2,4-D herbicide? What are alternative ways of reducing serious raspberry problems?

5. Are we spraying to reduce competition from light or from roots? How do forest managers determine the need for spraying? Do they need additional information in order to establish better guidelines for spraying?

6. What is the effect of 2,4-D and other herbicides on the quality of aspen suckering and conifer crop trees?

7. Does herbicide spraying promote the spread of root rot in conifers?

Although we have found answers to all these questions, we are not yet completely satisfied. We still do not know the optimum time to spray or at what intervals. Apart from some superficial studies, we lack quantitative growth data We know that shifts in composition occur after herbicide spraying but we lack precise information on species behavior. For example, 2,4-D will kill many brush species and thus change light conditions. Where this occurs, grass, sedge and raspberries may proliferate and other new species may invade the herbicide-treated area to create worse conditions for conifer crop trees. Tall grasses with medium blade widths such as bluejoint (*Calamagrostis canadensis* [Michx.] Nutt.) create more problems than fine grasses of the genera *Poa, Panicum* and *Muhlenbergia* even though approximately 1,000 stems of medium grass occupy the same space as 40,000 stems of fine grass.

Other problems presented by Sutton (1958) but not listed and discussed here should not be forgotten. There are still inconsistencies in herbicide spraying results.

Immediately after spraying, foresters get the impression that competing vegetation has been killed. However, after spraying with phenoxy herbicides (2,4-D and 2,4,5-T), grasses, sedges and raspberries increase in number. In some instances, species such as speckled alder (*Alnus rugosa* [Du Roi] Spreng.) and green alder (*A. crispa* [Ait.] Pursh), trembling aspen (*Populus tremuloides* Michx.), hazel (*Corylus cornuta* Marsh.), mountain maple (*Acer spicatum* Lam.) and balsam poplar (*Populus balsamifera* L.) tend to resucker. The rate of growth of these suckers and the extent of their influence on crop trees over time has not been documented.

Acceptable levels of resuckering among brush species and all other competitive species are not known. The extent of grass and sedge proliferation has not been documented nor have problem species been identified. It is hoped that the Pest Control Section of the Ontario Ministry of Natural Resources will be able to provide some answers in the near future when assessment plots have been visited for several consecutive years to determine the efficacy of 2,4-D, glyphosate, Velpar® and other herbicides that may be used in the future.

LONG-TERM PERFORMANCE OF DESIRABLE VEGETATION

Several years ago OMNR's Northern Forest Research Unit began to investigate the long-term effects of 2,4-D and 2,4,5-T on the growth of balsam fir (*Abies balsamea* [L.] Mill.) on sandy loam, silt loam and clay loam sites throughout northern Ontario (Lehela, unpublished data). The results of that investigation are herein presented to point out the long-term benefits that might be realized with other more desirable conifer species.

Between 1975 and 1978 seven cutovers were examined in the OMNR administrative districts of Hearst, Terrace Bay and Thunder Bay covering Site Regions 4W (Pigeon River) and 3E (Lake Abitibi) (Hills 1952, Burger 1972). In all, 6,967 mil-acre (2 m x 2 m) plots were examined on 822 ha of cutovers for stocking of tree and brush species while 1,665 mil-acre plots were examined to obtain 789 balsam fir trees for stem analysis samples. From sprayed and unsprayed areas balsam fir were sampled for each of the five consecutive 50 cm height classes (at the time of spraying) for trees less than 2.5 m in height.

Tree volumes using Smalian's formula (Avery 1967) were established for all bench-mark years, namely -5, 0, +5, +10, +15 or +20 years in relation to the year of phenoxy-herbicide spraying.

The results of this investigation have been condensed into a graphic presentation to show only area responses in height growth so that comparisons can be made with limited data for spruce (*Picea* spp.).

In general, immature decay-free (98%) balsam fir on unsprayed areas grew only marginally during the one pre-spray and one to four post-spray 5-year periods. The application of phenoxy-herbicide resulted in significantly increased ($P<0.01$) diameters at ground level, heights (Fig. 1), volumes and successive 5-year periodic post-spray growth rates in comparison with those of trees on control areas. Five years after spraying, net gains in volume per tree of 153%, 51% and 165% were obtained over the controls on sandy, clay and silt loam sites, respectively.

The percent differences in total heights and periodic height increments of balsam fir growing on sandy, silt and clay loams are presented in Table 1. It is evident that responses differ on different soils and that percent differences eventually decline.

Table 1. Percentage differences in total heights and periodic 5-year height increments of balsam fir growing on sprayed and unsprayed areas on sandy, clay and silt loam sites in northern Ontario.

	% differences in total height in post-spray years of				% differences in 5-year height increments during post-spray years of			
Soil type	+5	+10	+15	+20	1-5	6-10	11-15	16-20
Sandy loam	47	-	-	-	158	-	-	-
Clay loam	19	60	-	-	29	156	-	-
Silt loam	51	73	74	66	163	127	75	42

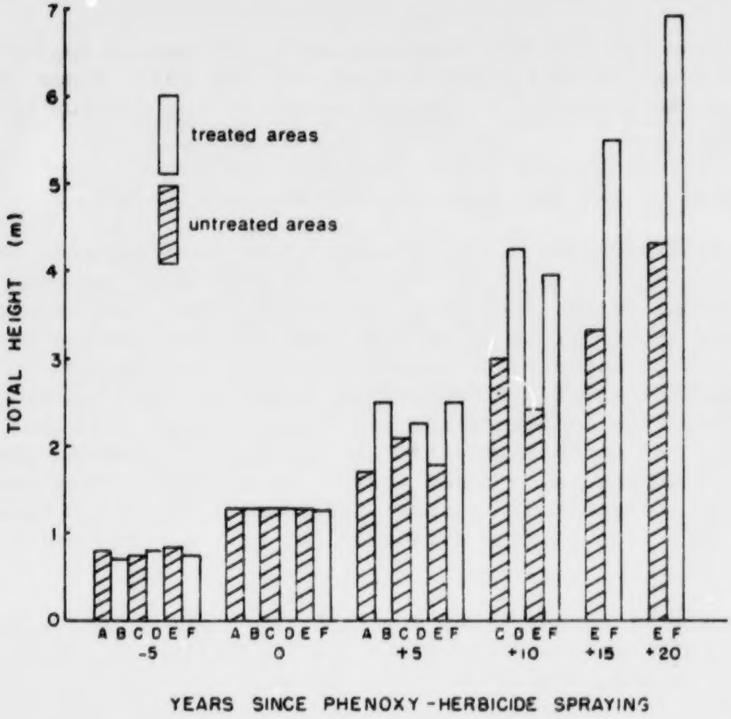

Figure 1. Weighted mean heights of balsam fir on untreated and treated sandy (A,B), clay (C,D) and silt (E,F) loam sites at -5, 0, +5, +10, +15, +20 years in relation to phenoxy-herbicide applications in northern Ontario.

The foregoing results show where there are gaps in our knowledge and suggest that more work is needed on sandy and clay loam sites. The data indicate that balsam fir performs considerably better on sprayed areas after even a single aerial application of phenoxy herbicides. The common method of expressing results in Table 1, however, does not reveal when a second spray is needed. The declines in growth are artifacts caused by the formula which uses total tree size, the denominator increasing with time. Other ways of expressing growth benefits are being examined for future use.

SHORT-TERM EFFECTS OF PHENOXY HERBICIDE SPRAYING ON HEIGHT GROWTH OF SPRUCE

Two separate studies conducted near Kapuskasing, Ontario did not show that spruce benefit from phenoxy herbicide spraying (Day 1974, Bunce 1979). Other data (Anon. 1964) collected for White River do not help to resolve the issue since no trees were measured in unsprayed areas. Since balsam fir did show response to single aerial applications of phenoxy herbicides, existing data for spruce (Day 1974, Bunce 1979) were processed by the author in a similar manner at the request of Kapuskasing District.

The results of the two separate data analyses follow.

Bunce (1979) examined 3,110 mil-acre plots covering four lowland and two upland site types. On 1,253 upland mil-acre plots he measured six post-spray annual height increments of 165 dominant, 137 co-dominant and 152 suppressed spruce trees in an area that was 36% stocked to spruce. He pooled all trees to compare the growth of spruce in sprayed and unsprayed stands regardless of differences in height at the time of spraying. Separating his data into dominance classes (Table 2), we find that there were more dominant and co-dominant trees in the sprayed than in the unsprayed area. However, there is no indication of which trees were initially dominant, co-dominant or suppressed during the 2,4-D spraying, and which trees were free to grow during all or part of the period.

Table 2. Proportion of spruce trees dominant, co-dominant and suppressed on upland sites six years after 2,4-D spraying near Kapuskasing, Ontario (based on data of Bunce, 1979).

		Spruce stocking		
Site type	2,4-D treatment	Dominant	Co-dominant	Suppressed
Feather-moss	Lowland control	1	9	7
	0.63 kg ai/ha	5	1	1
	1.61 kg ai/ha	0	0	0
	Upland control	5	7	12
	1.61 kg ai/ha	9	5	6
Upland	Lowland control	33	24	12
	0.63 kg ai/ha	0	0	0
	1.61 kg ai/ha	9	1	3
	Upland control	39	35	50
	1.61 kg ai/ha	64	55	61

Tables 3 and 4, in which I have used data provided by Bunce (1979) but have removed differences in initial tree heights, summarize the mean annual height increments for representative years. It is evident that trees over 50 cm tall benefited from the spraying, but only for three years on average, before a decline began. On average, six years after spraying, dominant, co-dominant and suppressed spruce were 16%, 7% and 15% taller in the area sprayed with phenoxy-herbicide than in the unsprayed area.

Table 3. Mean height growth of spruce near Kapuskasing, Ontario on feather moss sites sprayed in 1971 with 2,4-D (based on data of Bunce, 1979).

2,4-D treatment (kg ai/ha)	Spruce height class in 1971	Crown class 1977	No. of trees	Total height (cm)		Annual height increment (cm)		
				1971	1977	1971	1974	1975
0	1-50	D	4	28.6	123.2	10.0(3)	12.2(4)	19.6(4)
		CD	1	10.5	50.5	-	8.5	6.5
		S	2	26.0	55.8	4.5(2)	4.5(2)	4.5(2)
1.61	1-50	D	4	27.6	122.0	12.8(2)	19.1(4)	17.4(4)
		CD	0	-	-	-	-	-
		S	2	26.5	52.5	5.2	5.5	3.2
0	51-100	D	1	57.5	122.5	4.0	12.0	9.0
		CD	1	73.5	103.5	3.0	7.0	3.5
		S	1	68.5	98.0	8.5	4.0	5.0
1.61	51-100	D	2	62.2	162.8	13.2	17.0	16.0
		CD	0	-	-	-	-	-
		S	0	-	-	-	-	-
0	101-150	D	0	-	-	-	-	-
		CD	2	123.0	181.8	6.2	13.0	9.0
		S	3	118.3	151.0	6.8	4.7	2.7
1.61	101-150	D	1	128.5	245.5	17.0	24.0	28.5
		CD	3	132.2	213.7	7.3	9.7	12.2
		S	0	-	-	-	-	-
0	151-200	D	0	-	-	-	-	-
		CD	1	161.5	239.0	11.0	12.0	16.5
		S	0	-	-	-	-	-
1.61	151-200	D	1	179.0	339.0	22.0	36.0	25.0
		CD	2	165.0	251.0	10.0	15.0	13.5
		S	1	194.5	229.5	8.0	8.0	5.0

Note: D = dominant
CD = co-dominant
S - suppressed

Values in parentheses indicate changes in number of trees.

Table 4. Mean height growth of spruce near Kapuskasing, Ontario on upland sites sprayed in 1971 with 2,4-D (based on data of Bunce, 1979).

2,4-D treatment (kg ai/ha)	Spruce height class in 1971	Crown class 1977	No. of trees	Total height (cm) 1971	Total height (cm) 1977	Annual height increment (cm) 1971	Annual height increment (cm) 1974	Annual height increment (cm) 1975
0	1-50	D	28	23.6	116.0	8.5(13)	18.6(28)	17.8(28)
		CD	13	24.0	83.5	5.0(11)	12.5(13)	10.4(13)
		S	18	21.2	60.7	5.8(10)	7.7(18)	5.8(18)
1.61	1-50	D	25	27.1	116.6	8.6(17)	16.9(25)	15.6(25)
		CD	32	27.6	91.1	8.2(25)	12.0(32)	11.0(32)
		S	30	24.3	72.1	6.0(18)	9.3(30)	8.5(30)
0	51-100	D	1	99.5	151.0	8.0	10.0	4.5
		CD	5	92.2	148.2	8.4	11.2	9.7
		S	11	70.7	110.8	6.3(10)	8.4(11)	7.4(11)
1.61	51-100	D	25	73.1	183.7	14.1(24)	23.9(25)	18.7(25)
		CD	17	77.9	173.2	12.0	17.8	17.1
		S	8	66.1	132.2	9.8(8)	15.3(8)	9.9(8)
0	101-150	D	1	148.5	238.5	13.5	14.0	15.5
		CD	9	122.7	189.2	9.6	12.2	12.3
		S	3	115.5	189.7	14.0(3)	13.3(3)	12.0(3)
1.61	101-150	D	8	129.1	255.7	16.7	24.8	26.8
		CD	3	110.5	193.0	10.3	16.0	15.2
		S	1	132.0	206.0	22.5	4.0	16.0
0	151-200	D	3	179.7	276.8	16.3	16.0	18.7
		CD	5	172.6	256.4	11.9	19.5	12.2
		S	3	167.2	216.7	7.5	8.7	9.7
1.61	151-200	D	0	-	-	-	-	-
		CD	0	-	-	-	-	-
		S	0	-	-	-	-	-

Note: D = dominant
CD = co-dominant
S = suppressed

Values in parentheses indicate changes in number of trees.

A second inconclusive study was conducted by Day (1974) near Kapuskasing on an area that was 15% stocked with spruce. In total, 1,800 mil-acre quadrats were examined and two-year height increments and total heights of 120 black spruce (*Picea mariana* [Mill.] B.S.P.) and 150 white spruce (*P. glauca* [Moench] Voss) were recorded. Growth on both areas was compared, with all trees pooled regardless of differences in heights at time of spraying. I was not able to improve upon Day's inconclusive findings by stratifying trees according to height class because the sample sizes were small and I was unable to sort out the suppression effects of conifers on other conifers.

Tables 3 and 4 demonstrate the problems that are hidden by surveys which pool all data. It is quite common for data to be missing, and with small sample sizes it is difficult to find enough matching trees by random selection. Variations in tree ages and ingrowth also confound results, especially if natural regeneration is being examined. Throughout cutovers it is evident that sample sizes of crop trees in all three crown classes (dominant, co-dominant and suppressed) are not equivalent. Less evident is the fact that crown class ratings on a particular occasion do not indicate what proportion of the crop trees changed their crown class ratings.

Assessing artificial regeneration has more problems than assessing natural regeneration. Several years after planting it is difficult to sort out the influences of stock ages, types and root systems, seed and nursery sources, planting methods, containers and depths, different types of site preparation and the role of different height and density classes of competition without destroying the trees. With both natural and artificial regeneration, insects, disease, frost, flooding, snow, drought, microsites and variations in height classes and densities of competing species all cause problems. The major effect of these is to reduce the benefits that might result from herbicide application. The extent of this reduction still needs to be documented, and annual assessments are essential.

FUTURE POTENTIAL NEW CHEMICAL TOOLS

With the recent loss of 2,4,5-T and the inconsistency of 2,4-D, the Ministry is currently examining two new herbicides, glyphosate (Roundup®) and Velpar® for operational use. Glyphosate is a foliage-applied translocated herbicide reported to be very effective on deep-rooted perennial species and on annual and biennial species of grasses, sedges and broadleaved weeds (Anon. 1979). Velpar®, on the other hand, is considered a foliage or soil-applied translocated herbicide that controls many annual and biennial weeds, woody vines and most perennial weeds and grasses.

Tables 5 and 6 summarize, respectively, one- and two-year effects of different dosages of glyphosate on the major competitive species, although not all species are present in all treatments. Increasing the volume of carrier does not improve the kill of competition. In the north the August spray seems to control raspberries more effectively than the July spray whereas in the south, September spraying is better than August spraying. This may be caused by differences in growing season between southern and northern Ontario. Control of grass follows a similar pattern. The numbers presented in Tables 5 and 6 confound the picture since grasses with coarse, medium and fine blade widths are pooled. For example, 40,000 stems of fine grass, such as scratch grass (*Muhlenbergia glomerata* [Willd.] [Trin.] Parodi) occupy the same space as 1,000 stems of medium grass such as bluejoint but do not have the same smothering effect on conifers.

Two-year field observations indicate that raspberries and grass plus sedge are effectively reduced as Velpar® dosage increases. The 2.2 kg ai/ha dosage is probably sufficient since the 4.4 kg ai/ha rate does not improve the efficacy of Velpar® treatments. Further observations will have to be made in this study to confirm whether this trend lasts more than two years. The work is going on at the present time.

Collectively, Tables 5 and 6 show that glyphosate dosages greater than 1 kg ai/ha are required to control grass, raspberries and poplar. Further work with pre-spray assessments and a few consecutive years of post-spray observations with poplar suckering are required to confirm the present trends. Resuckering of poplar does not occur at least during the first two years after a single application of glyphosate. Data from individual locations indicate that between 20% and 90% of the raspberries may be killed. Pooling results from different locations where soils differ tends to alter the minimum and maximum responses obtained. Detailed soil surveys on all sample plots at all locations will help to determine the extent of confounding effects of different sites such as sandy, silt and clay loam sites. Continuing analysis reveals that species changes in grasses need to be documented and data summarized concisely. If this is not done, ocular observations will be contradicted by numerical observations and thus wrong conclusions may be drawn with respect to the efficacy of a given herbicide.

Data from the one location where Velpar® was used indicate that between 20% and 90% of the raspberries can be killed if a dosage greater than 2.2 kg ai/ha is used. Ocular estimates show that Velpar® kills up to 90% of grass per mil-acre plot while counts of live stems show that there are fewer stems of grass as the Velpar® dosage increases. Both methods confirm that Velpar® does control grass species. Data gathering will continue in areas to which Velpar® has been applied by ground sprayers and aircraft.

Table 5. Density and condition of vegetation one year after aerial application of glyphosate in July and August near Kapuskasing and Kirkland Lake.

Month of application	Rate of active ingredient and carrier		Top kill rating	Average number of stems per 2x2 m (mil-acre) plot of							
	kg/ha	L/ha		Alders	Trembling aspen	Cherries	Hazel	Mountain maple	Willows	Rasp-berries	Grass and Sedge
July	0	34	0	2	0	2	1	2	1	27	1046
			100+	0	0	0	0	0	0	6	M
	0.55	34	0	0	1	1	0	0	1	17	396
			31-60	0	0	0	0	1	0	0	M
			100+	0	0	0	1	0	1	19	M
	1.10	34	0	0	0	1	0	0	1	13	108
			100+	0	0	1	3	0	0	31	M
	2.20	34	0	0	0	2	0	1	0	18	259
			100+	4	0	1	0	1	0	11	M
	0	68	0	0	1	4	0	0	0	34	551
			100+	0	0	1	0	0	0	13	M
	0.55	68	0	0	1	8	0	0	2	43	773
			100+	0	0	1	0	0	0	18	M
	1.10	68	0	0	1	2	0	0	1	33	263
			100+	0	0	1	0	0	0	21	M
	2.20	66	0	0	0	5	0	0	0	20	345
			100+	0	0	0	0	0	0	26	M
August	0		0	1	0	0	0	0	3	48	1023
			100+	0	0	0	0	0	0	7	M
	0.55	34	0	0	1	1	1	0	3	10	1327
			1-30	0	0	0	0	0	1	0	M
			31-60	0	1	0	0	0	1	0	M
			100+	0	0	1	0	0	4	21	M
	1.10	34	0	0	0	0	0	0	1	12	947
			100+	0	1	0	1	0	1	33	M
	2.20	34	0	1	0	0	0	0	2	10	76
			100+	1	0	1	0	0	1	24	M
	0.55	68	0	2	1	1	0	0	1	27	2340
			1-30	0	0	0	0	0	0	1	M
			31-60	0	0	0	0	0	0	1	M
			100+	2	0	0	0	0	0	34	M
	1.10	68	0	0	0	1	0	0	2	17	838
			31-60	0	0	0	0	0	0	1	M
			100+	0	0	1	1	0	1	35	M
	2.20		0	0	0	1	0	0	1	15	2934
			100+	0	1	0	2	0	1	33	M

Note: M - missing observations

Sample size = 50 and 70 mil-acre plots for sprayed and unsprayed areas

Top kill rating
0 = healthy plant
1-30 = 1-30% top dead
31-60 = 31-60% top dead
100+ = dead plant and no resuckering

Table 6. Density and condition of vegetation two years after aerial application of glyphosate in August and September north of Thunder Bay and Tweed, Ontario.

Month of application	Rate of active ingredient and carrier kg/ha	L/ha	Top kill rating	Average number of stems per 2x2 m (mil-acre) plot of Alders	Trembling aspen	Cherries	Hazel	Mountain maple	Willows	Rasp-berries	Grass and Sedge
August	0	34	0	2	14	0	0	0	3	6	295
			100+	0	0	0	0	0	0	0	M
	0.55	34	0	16	20	0	0	0	2	8	1167
			100+	1	0	0	0	0	0	0	M
	1.10	34	0	0	0	0	0	0	1	5	845
			100+	8	1	0	0	0	0	1	M
September	0	34 or 68	0	0	2	0	2	0	1	4	148
			100+	0	1	0	2	0	0	1	M
	0.55	34	0	2	2	1	1	0	0	14	274
			100+	1	2	1	0	0	0	11	M
	1.10	34	0	0	2	0	1	0	0	23	313
			1-30	0	1	0	0	0	0	0	M
			100+	0	1	0	0	0	0	6	M
	2.20	34	0	0	0	0	3	0	0	13	539
			100+	1	2	0	1	0	0	4	M
	0.66	68	0	1	1	0	2	0	0	7	252
			100+	0	0	0	0	0	0	3	M
	1.32	68	0	1	1	1	0	0	0	15	281
			100+	1	1	1	0	0	0	1	M
September	2.64	68	0	1	1	1	1	0	0	13	197
			100+	2	2	1	0	0	0	5	M

Note: M = missing observations

Sample size = 50 and 60 mil-acre plots for sprayed and unsprayed areas

Top kill rating 0 = healthy plant
1-30 = 1-30% top dead
100+ = dead plant and no resuckering

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NON-CHEMICAL TENDING IN THE BOREAL MIXEDWOOD FOREST OF ONTARIO

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Non-chemical methods of controlling competing vegetation in established stands have always been a component of the silvicultural program of some forest districts. In view of our overall goals, the need for practicable control methods, and the increasing public objection to chemical use, non-chemical tending may be a necessary alternative in future programs.

Les méthodes de lutte sans produits chimiques contre la végétation concurrente dans les peuplements régénérés ont, depuis toujours, fait partie du programme de soins culturaux de certaines circonscriptions forestières. Compte tenu de l'ensemble des objectifs, de la nécessité d'avoir des méthodes pratiques de lutte, et de l'opposition de plus en plus forte du public à l'emploi de produits chimiques, il faudra peut-être se passer de ces produits dans les futurs programmes.

Continual tending to maintain survival, improve quality and increase performance is necessary for the protection of our initial investment in stand establishment. Miller (1977) states that failure to tend plantations will result in additional mortality, poor performance, and extended rotations. He stresses that tending should be scheduled at the time of planting and should be part of a total silvicultural package based on site conditions and related competition.

Thinning, as part of the tending phase, has not been widely applied in northern Ontario nor have standards been developed for the boreal mixedwood forest. Thinning should be carried out on a selection basis to leave trees standing with straight stems, healthy, full crowns, and single, long leaders.

Release work involves freeing young stands from undesirable individuals which overtop them or are likely to do so. The effect of root competition is seldom, if ever, considered when determining the need for release work. Cleaning and liberation cuts are the two operations most commonly undertaken for tending in established stands.

Although the aerial application of chemicals is undoubtedly cheaper, non-chemical tending is usually considered in isolated stands located long distances from an airstrip, in small demonstration areas, in environmentally sensitive areas and as part of specific selective treatments. Public antagonism to herbicides is increasing because of the obvious effects on woodlands and possible effects on health and environmental quality (Weingartner and Basham 1979). Controversy has surrounded the relative safety and the environmental impact of herbicides. There is also evidence that herbicide sprays trigger higher than average levels of root rot in planted conifers. *Armillaria mellea* (Vahl ex Fr.) Kumm. thrives in any dead, woody material in the soil and it grows especially well in hardwood stumps and dead roots. Herbicide-killed roots of shrubs and unwanted hardwood species become heavily infected with *A. mellea*, which may spread to planted conifers and kill them.

Specific knowledge of the growth requirements for boreal mixedwood species is generally lacking and the degree, type, and timing of treatment are often determined through trial and error.

Furthermore, economic rather than biological considerations often determine the time of year when projects are initiated. Funds are made available in late fall or early winter when make-work government programs begin and budget surpluses are realized.

Constant examination of stands is essential to determine the need for release. Cleaning should be carried out when the competition is over-topping, shading or mechanically injuring the young crop trees. Summer cleaning, up to late August, reduces sprouts. Sprouts from ground level stumps are often weak and die within a year or two.

The sandvic brush axe has traditionally been used to clean young stands. The smaller diameter trees (under 10 cm DBH) which are over-topping crop trees should, ideally, be partially cut through and pushed down so that the stem is not completely severed from the stump. The theory behind this is that these saplings will remain alive, but in a weakened condition. Saplings with a DBH greater than 10 or 12 cm should be girdled by removing completely a strip of outer and inner bark around the tree. It is imperative that the inner bark be completely severed and removed in a strip approximately 2.5 cm wide around the entire circumference of the tree, especially in poplar (*Populus* spp.). If this is not done, the poplar will grow as vigorously as ever. Care should be taken not to drop felled trees on the crop trees. In the winter leaders are very brittle and break easily.

A less common practice is to break poplar suckers by hand. However, suckers are usually too small at age one for this practice to be feasible, and when they are beyond age two, the added growth makes it difficult to perform during a full day.

Jack pine (*Pinus banksiana* Lamb.) regeneration often grows in clumps as a result of several seedlings germinating from a single cone. The result is similar with artificial spot seeding, where a large number of seeds germinate in a small area. Competition among these developing seedlings restricts normal growth. To release these stands, inferior pine trees should be cut out. The stem showing best height, diameter and form in the clump is selected and the others are removed. Stems to be removed should be cut below the lowest living branches to ensure that regrowth does not occur (M.Z. Leschishin, Unit Forester, Wawa District, OMNR, personal communication 1980).

Only direct competition, usually only that which is within a 1.5 m radius of the tree to be released, should be cleaned so as to reduce costs and lessen chances of monocultures which are vulnerable to insects and diseases.

It is generally felt that the use of brush saws rather than the traditional axe or sandvic methods in stands with over 10,000 stems per ha will result in significant cost savings (Fox and Vanderkleyn 1978). The clearing saw is safer than a chainsaw, more efficient and less tiring for the operator. Use of the brush saw for cleaning has only recently received attention in northern Ontario. The most popular model used by OMNR for operational trials is the 165R Husqvarna. The clearing saw is a most effective tool which improves production and facilitates work. With good work technique and a physically able operator, production is high (up to 1.5 ha per man day). It appears that the brush saws are put to best use in the densest of stands (those with more than 10,000 stems per ha). Areas with fewer than 10,000 stems per ha should be cleaned manually with an axe or sandvik. The lower density requires more unproductive time in swinging the saw to individual stems and there is a greater chance of cutting off the trees which were to be released.

The handle bars must be adjusted carefully to ensure a comfortable working position. Incorrect adjustments can cause stress and pain in the arms, shoulders, and back. Since people are physically different, the position of the handles has to be adjusted to the size of the individual operator. The saw should be balanced so that the blade on a fully tanked saw is 20 to 30 cm above the ground.

The sharpness of the blade plays an important role in production. It is therefore desirable to work with the sharpest possible blades. Any blade, regardless of type, should be changed or filed if it strikes a stone.

The work is carried out in strips of 3 to 10 m. The width should be less in high density stands than in low density stands. Here it is preferable to use the saw sideways in a pendulum movement. The length of the strips also has to be adjusted to stand density and is normally 50 to 100 m. If it is too short, the equipment (fuel, etc.) has to be moved many times. If it is too long the worker may have to walk some distance for refueling.

The saw should always be operated with a full throttle for cutting, and the desired direction of falling should be considered when the blade is being applied. The 11 o'clock area gives the best control; it should be used when there is a risk of damage to remaining stems or of hitting a stone. Use of the 8 o'clock sector of the blade should be avoided. Hardwood brush can easily stick between the blade and blade guard. If this happens, one should first try to roll the blade backwards against a stump. If this is not enough, the motor must be stopped, the saw disengaged from the harness and the guard cleaned by hand.

It is important to be conscious of safety at all times when using brush saws, and to follow closely the instructions given in the owner's manual. The primary danger is not to the cutter, but to those near him. The cutters must always be well separated in the respective blocks. Trees 20 cm or larger should be left for cutting or girdling later with an axe or sandvic.

Safety clothing is mandatory when one is using the brush saw: safety boots, pants, hard hat with eye shield, and ear protection to avoid impaired hearing should all be included.

Problems encountered in the use of the brush saw can usually be attributed to unsuitable stands, inexperienced workers or insufficient planning, abused or poorly maintained equipment or improperly adjusted harness.

It should be noted that winter operations with the brush saw are restricted when snow measures over 15 cm.

Cleaning costs are greatly affected by the capabilities of available manpower. Low production is generally associated with government assisted make-work programs. This can be as little as 0.07 ha per man day (Latt 1972). Other factors include the number of stems to be cleaned, height and diameter, species, ground conditions, weather and logging or cleaning residues.

As an alternative to hourly paid workers, the Nipigon forest district has let piecework contracts. By this method costs are fixed beforehand. Payment is made only after areas have been satisfactorily completed. Present costs are averaging approximately $200/ha.

Since cutting of hardwood growth may result in a great number of root and stump shoots, the forest manager should anticipate the need for repeated cleaning in younger stands and plantations.

It is difficult to obtain statistical evidence of the results achieved by tending treatments. Willcocks (N.D.) notes that one reason for the poor growth performance of an unmanaged white spruce (*Picea glauca* [Moench] Voss) stand in comparison with that of the adjacent stand is the heavy competition from non-spruce species. In the Nipigon forest district, Clemmer and Atkins (1979) noted that the cutover failure rate is 39% because of poor stocking and vegetative competition. Hambly (1980) maintains that there is a need for continuous cleaning of young spruce stands to remove competing vegetation if the "free-to-grow" status of spruce is to be maintained throughout the juvenile stages of stand development.

There is little or no documented information on the economic efficiency of post-release treatments for specific site and stand conditions in the boreal mixedwood forest. Additional research efforts should provide the knowledge we need to manage our young, high-quality stands through to rotation.

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LOSSES FROM AND CONTROL OF SPRUCE BUDWORM AND OTHER INSECTS IN THE BOREAL MIXEDWOOD FOREST

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The most important insect pests in the boreal mixedwood forest are spruce budworm, forest tent caterpillar, large aspen tortrix, and birch skeletonizer. The biology, life cycle, type of damage caused by these insects and potential forest losses as a result of infestations are described, and control measures are discussed.

Les principaux ravageurs de cette forêt sont la Tordeuse des bourgeons de l'Épinette, la Livrée des forêts, la Tordeuse du Tremble, la Squelletteuse et la Tenthrède du Bouleau. La biologie, le cycle vital, le type de dégâts des insectes et les pertes forestières résultant de leurs infestations ainsi que les moyens de lutte sont discutés.

A considerable number of insect pests can cause injury to the host tree species of the boreal mixedwood forest. The most important of these insect pests are listed below.

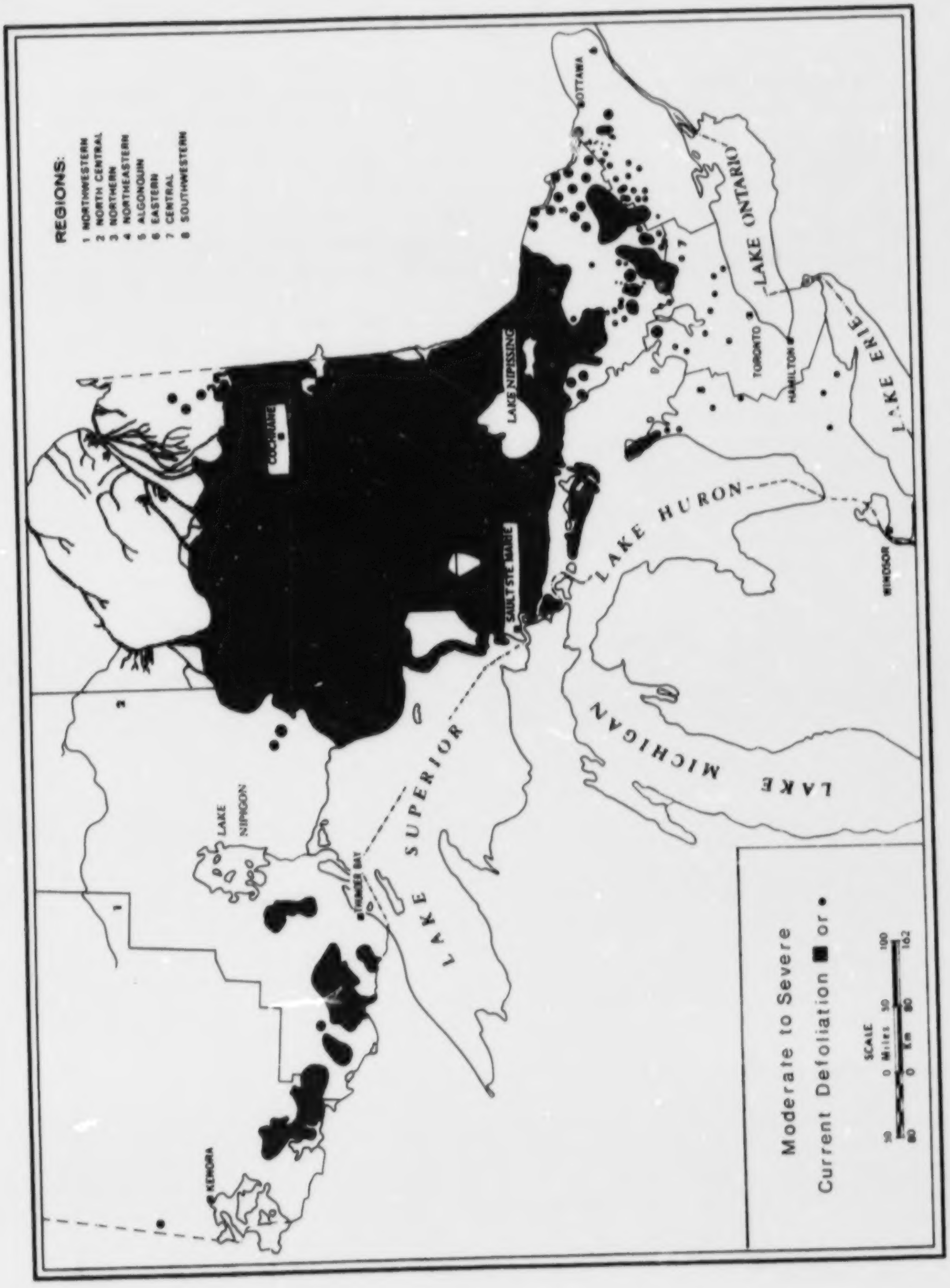
Common name	Scientific name	Host(s) affected
Spruce budworm	*Choristoneura fumiferana* (Clem.)	balsam fir white spruce black spruce
Forest tent caterpillar	*Malacosoma disstria* Hbn.	trembling aspen white birch
Large aspen tortrix	*Choristoneura conflictana* (Wlk.)	trembling aspen
Birch skeletonizer	*Bucculatrix canadensisella* Cham.	white birch

This list is based on considerations of severity of attack and the extent to which the forest is affected during outbreaks, on frequency of occurrence of outbreaks and, in very general terms, on the value of the host tree affected. Consequently, I will limit my discussion to spruce budworm, forest tent caterpillar, large aspen tortrix and seed and cone insect pests of black spruce (*Picea mariana* [Mill.] B.S.P.). (Spruce budworm also falls into the last-mentioned category.) The birch skeletonizer is one of a number of insect pests on white birch (*Betula papyrifera* Marsh.) that are found frequently at outbreak levels over large areas. However, there is little point in discussing insects affecting white birch because this species plays an insignificant role in the forest economy of Ontario at the present time.

The spruce budworm has been, is, and will likely continue to be, the most destructive insect in Ontario's forests. The present outbreak started in 1967. As of July 1980, some 18.85 million ha of forest within the province were infested at population levels capable of causing moderate-to-severe defoliation (Fig. 1). Tree mortality is evident throughout some 8.36 million ha (Fig. 2). It should be kept in mind that the area affected by budworm represents the gross area within which stands containing one or more of the major host species show evidence of budworm feeding.

The primary hosts of budworm in Ontario are balsam fir (*Abies balsamea* [L.] Mill.), white spruce (*Picea glauca* [Moench] Voss) and black spruce. The insect also feeds on larch (*Larix* spp.) and hemlock (*Tsuga* spp.). The adult moth deposits eggs in masses in July on the needles of host trees. The eggs hatch in about 10 days and the young larvae spin silken hibernaculae in suitable sites (such as inside staminate flower cups or under bark scales) where they overwinter. The larvae become active and emerge from the hibernaculae in early or mid-May when they generally mine needles before entering buds. The larvae feed on the new foliage of developing shoots, and in late June or early July, when they are fully grown, they change to pupae in the feeding sites. The pupae become moths in about 10 days, completing the life cycle. The budworm is a univoltine insect, i.e., it produces one generation per year.

Injury to infested trees is cumulative in that all or part of the new foliage produced on an infested tree is consumed each year. In light or moderate infestations, injury consists of partial loss of new foliage in the upper portion of the crown. If the infestation collapses after a year or two the trees soon outgrow the loss. In heavy, persistent infestations, all of the new foliage may be consumed for several successive years. Diameter growth is reduced during the first year of appreciable defoliation and continues in relation to the degree of defoliation and number of consecutive years of attack. Top killing of balsam fir usually occurs after 3 or 4 years of severe infestation and some suppressed trees may die. Mortality of balsam fir usually begins after about 5 years of severe infestation. In sustained outbreaks, nearly all of the merchantable volume of balsam fir may be dead by the eighth, ninth or tenth year of


REGIONS:
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2 NORTH CENTRAL
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4 NORTHEASTERN
5 ALGONQUIN
6 EASTERN
7 CENTRAL
8 SOUTHWESTERN
KENORA
LAKE NIPIGON
THUNDER BAY
LAKE SUPERIOR
SAULT STE MARIE
COCHRANE
LAKE NIPISSING
OTTAWA
LAKE HURON
LAKE MICHIGAN
LAKE ONTARIO
TORONTO
HAMILTON
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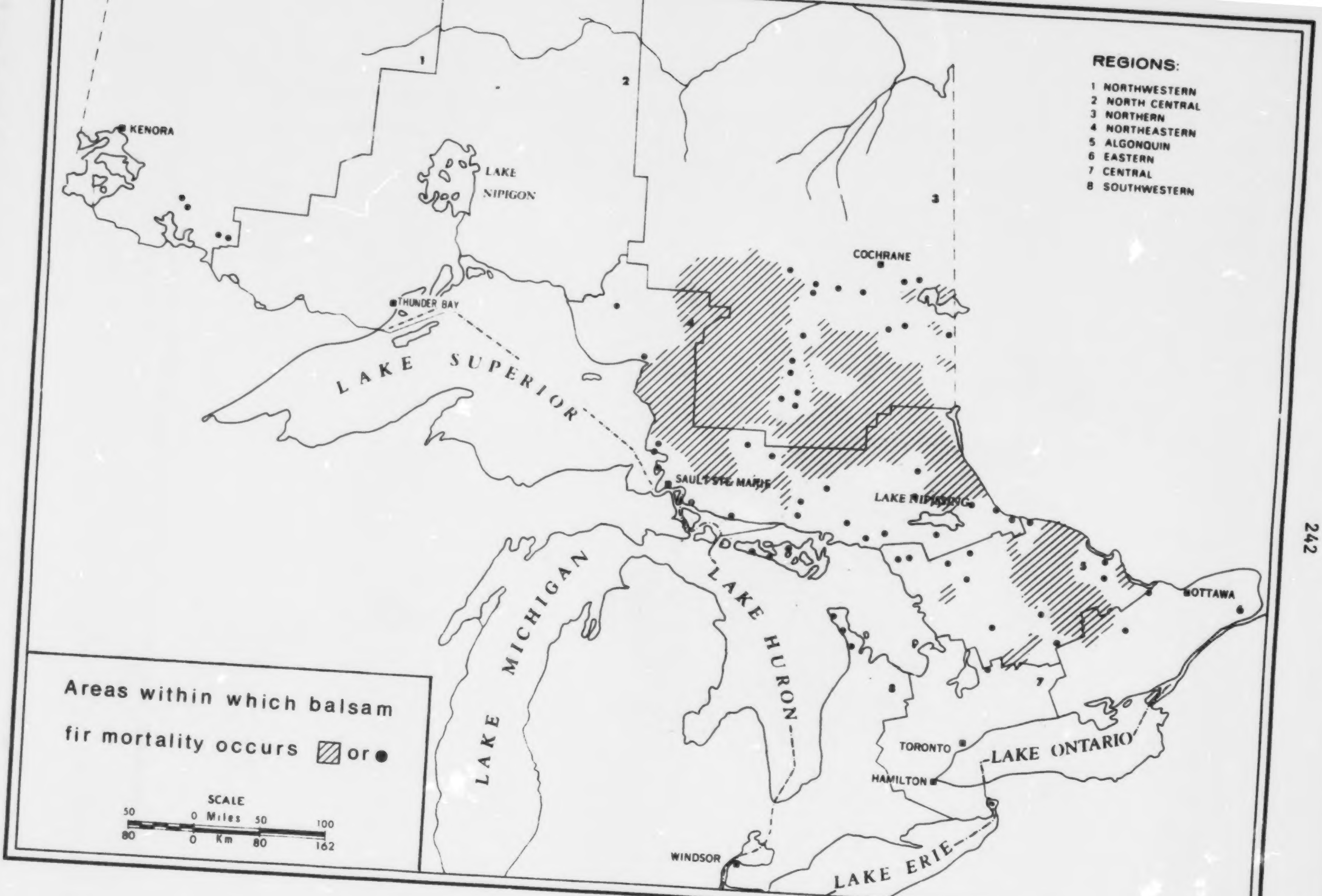
Figure 1. Spruce budworm damage map for 1980.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KENORA
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COCHRANE
SAULT STE MARIE
LAKE NIPISSING
OTTAWA
LAKE MICHIGAN
LAKE HURON
TORONTO
HAMILTON
LAKE ONTARIO
WINDSOR
LAKE ERIE
Areas within which balsam fir mortality occurs ▨ or ●
SCALE
50 0 Miles 50 100
80 0 Km 80 162

Figure 2. Spruce budworm-caused mortality, Ontario, 1980.

infestation. White spruce and black spruce growing in mixture with balsam fir are less susceptible but, nevertheless, in sustained infestations, half or more of the merchantable volume of these species (growing in association with balsam fir) may die. White spruce and black spruce trees start to die after 6-8 years of repeated severe defoliation. Pure stands of black spruce and isolated white spruce generally survive but surviving spruce trees that come under severe attack suffer reduced diameter and height growth and may be predisposed to disease and bark beetles.

The spruce budworm has many natural enemies including parasites and predators, birds, mites, spiders and several pathogenic organisms. Other important natural control factors are: 1) loss of young larvae through competition for new foliage in heavy infestations; 2) loss of young larvae as a result of cooler than normal temperatures and late frosts in spring; 3) loss of large larvae through starvation following complete defoliation; 4) loss of adults through dispersal.

The history of budworm outbreaks in Ontario has been determined from suppression patterns in the growth rings of white spruce trees. There have been nine outbreaks since the early 1700s: 1704, Lake Nipigon, lasted 10 years, only evidence for a budworm outbreak in the 18th century in Ontario; 1802, Lac Seul, Lake Nipigon; 1832, Central Ontario, Algoma; 1863, Lac Seul; 1911, Lac des Milles Lacs; 1921-1932, Central Ontario, Temagami, Sudbury; 1937-1950, Central Ontario, Algoma, Sudbury; 1940-1962, Nipigon, Lac Seul, northwestern Ontario; 1967- ? northwestern, northeastern and southern Ontario.

Budworm populations increase in forest stands with substantial proportions of maturing balsam fir, following a number of successive years characterized by clear sunny weather in June and July, conditions especially favorable for larval development and survival. Such areas of population buildup, known as focal points or epicentres of outbreaks, may be quite variable in size, and are the centres from which successive bands of infestation extend outwards. Outbreaks collapse when heavy tree mortality has reduced the food supply. The collapse may be triggered by unfavorable weather during the period of budworm development. As budworm populations decline, parasites, predators and disease become relatively more important and hasten the decline to endemic levels.

The loss of wood fibre as a result of tree mortality and reduced growth is one of the more obvious impacts of a spruce budworm outbreak. It is also stated in the literature (Prebble 1975) that "the period following destruction of extensive stands is one of high fire hazard. Several of the more massive forest fires in eastern Canada can be attributed to the presence of budworm-killed trees over large areas." Following a budworm outbreak, regeneration patterns are such that there is a tendency toward increasing proportions of balsam fir in the first decades of the succeeding stand. A similar pattern occurs after harvesting. Hence, whether budworm or harvesting has caused the removal of the original stand, balsam fir will constitute a large proportion of the next stand. As noted by Burgar (1963), the urgency, in terms of maintaining or increasing the supply of raw material for forest industries, becomes even more apparent when it is realized that the budworm-susceptible forest types occupy the upland sites, which are the areas of greatest potential growth.

Losses due to budworm must be considered in the context of Ontario's forests and forest industries. Table 1 lists the percentage composition by species (on the basis of volume) of primary growing stock on productive forest land in the four regions of northern Ontario and the Algonquin Region. Balsam fir is the fifth most prevalent species in the four northern regions, and increases in relation to other species from west to east across the north. Tables 2 and 3 list the percentage composition by species in the forest districts in the Northeastern and Northern regions, respectively. Note that balsam fir comprises some 17% of the primary growing stock in Kirkland Lake District and nearly 14% in Gogama, levels considerably higher than the regional average. Table 4 lists area of balsam fir working group expressed as a percentage of total productive area for the regions, for the district of the Northeastern and Northern regions and for several management units or townships. It can be seen that as we move from the overall picture (regions) to more local situations (districts, management units or townships), balsam fir becomes more of a factor in some locations. Volumes of balsam fir in balsam working groups for regions, districts, etc., are given in Table 5. The main point to be gained from these data is that balsam fir is common, albeit at relatively low levels, across Ontario, but frequently there are local concentrations. White spruce occurs in a similar fashion; however, the volume of white spruce is less than half (about 40%) that of balsam fir. The dominant species in the forests of northern Ontario is black spruce. On the basis of site (upland vs lowland) and other factors, at least half, perhaps closer to two-thirds, of the black spruce may be susceptible to injury by spruce budworm.

Direct losses as a result of tree mortality caused by budworm can be considerable. For example, some 815.5 million cu. m of pulpwood were destroyed in an outbreak in Quebec, New Brunswick, Maine and Minnesota between 1910 and 1920. Following an outbreak in northwestern Ontario in the 1940s and 1950s, it was estimated that 62.7 million cu. m of pulpwood were lost. This total consisted of 28.3 million cu. m of balsam fir, 18.1 million cu. m of white spruce and 16.3 million cu. m of black spruce. In 1976, in the six eastern provinces, it was estimated that budworm killed trees representing some 22 million cu. m of wood (about 42% of the 1976 harvest in these provinces).

It has been estimated that, as a result of the current outbreak in northeastern Ontario which has lasted for 14 years, more than 29 million cu. m of balsam fir have been lost (Table 6). This represents about 60% of the balsam fir volume within the 6.84 million ha of mortality. In 1979 the calculated loss of 7.25 million cu. m was about 50% of the total softwood volume harvested from Crown lands within the province. A

Table 1. Percentage composition (by volume and species) of primary growing stock on productive forest land in the forest regions of northern Ontario.[a]

	Region				
	Northwestern	North Central	Northern	Northeastern	Algonquin
Balsam fir	3.3	6.4	6.9	8.1	5.1
White spruce	1.2	1.8	3.1	4.6	2.6
Black spruce	47.3	48.3	48.2	17.4	1.7
Jack pine	25.5	14.8	9.6	11.6	.3
White pine	.4	.1	.4	5.4	7.2
Red pine	.2	T	T	1.8	1.7
White cedar	.5	.9	2.2	3.1	1.3
Tamarack	.1	.7	.9	.3	.2
White birch	5.6	9.9	8.6	16.9	5.1
Poplar	15.8	17.1	19.8	17.9	10.3
Red maple	T	T	.1	1.6	4.2
Ash	.1	T	T	.4	.6
Elm	T	T	nil	T	.6
Red oak	T	nil	nil	.3	2.3
Sugar maple	T	T	.1	6.8	36.3
Yellow birch	T	T	.1	3.0	9.6
Hemlock	T	T	T	.7	6.8
Beech	T	nil	nil	nil	3.3

[a] Source of data: Ontario Forest Resources Inventory.

T = Trace

Table 2. Percentage composition (by volume and species) of primary growing stock on productive forest land in the forest districts of the Northeastern Region.[a]

	District						
	Wawa	Sault Ste. Marie	Blind River	Espanola	Sudbury	North Bay	Temagami
Balsam fir	7.9	13.7	4.8	6.2	7.0	9.6	10.8
White spruce	3.3	4.6	3.2	6.2	7.3	4.3	4.8
Black spruce	32.7	16.7	12.2	9.0	6.4	7.2	14.0
Jack pine	13.3	7.5	27.1	13.8	12.3	2.4	8.0
White pine	.1	12.0	8.6	5.5	10.7	6.6	8.2
Red pine	T	T	2.2	2.0	4.2	2.2	3.8
White birch	14.3	18.8	17.2	16.7	21.1	16.2	20.8
Poplar	18.2	5.6	13.6	22.9	18.8	17.0	17.8
Sugar maple	4.2	10.3	6.7	5.2	3.0	16.5	3.1
Yellow birch	3.2	5.8	2.6	.8	1.0	6.0	2.0

[a] Source of data: Ontario Forest Resources Inventory.

T = Trace

Table 3. Percentage composition (by volume and species) of primary growing stock on productive forest land in the forest districts of the Northern Region.[a]

	District						
	Hearst	Kapuskasing	Cochrane	Kirkland Lake	Timmins	Gogama	Chapleau
Balsam fir	7.2	4.5	6.1	17.3	8.7	13.8	5.6
White spruce	3.7	1.8	3.2	2.2	6.5	2.0	4.1
Black spruce	47.7	59.6	65.4	25.0	27.5	18.9	29.5
Jack pine	7.6	3.2	3.9	21.7	13.9	25.9	19.1
White birch	5.9	4.4	5.2	12.7	15.6	16.0	16.3
Poplar	24.1	22.3	14.7	18.4	19.9	17.2	19.7

[a] Source of data: Ontario Forest Resources Inventory.

Table 4. Area of balsam fir working group expressed as a percentage of the total productive area.[a]

Region	District in the Northeastern Region	District in the Northern Region	Management unit or township
Northwestern - 3.2	Wawa - 9.4	Hearst - 6.9	Beemer - 7.8
North Central - 8.3	Sault Ste. Marie - 19.7	Kapuskasing - 3.5	Elliott - 39.4
Northern - 7.8	Blind River - 4.9	Cochrane - 4.4	Braithwaite - 33.4
Northeastern - 8.2	Espanola - 4.6	Kirkland Lake - 23.7	Black Sturgeon - 29.8
Algonquin - 5.7	Sudbury - 6.9	Timmins - 12.6	Burchell Lake - 20
	North Bay - 8.4	Gogama - 12.1	
	Temagami - 10.9	Chapleau - 7.8	

[a] Source of data: Ontario Forest Resources Inventory.

Table 5. Volume of balsam fir in balsam fir working groups expressed as cu. m/ha.[a]

Region	District in the Northeastern Region	District in the Northern Region	Management unit or township
Northwestern - 41.3	Wawa - 49.7	Hearst - 74.9	Beemer - 23.1
North Central - 52.5	Sault Ste. Marie - 53.2	Kapuskasing - 47.6	Elliott - 79.8
Northern - 59.5	Blind River - 50.4	Cochrane - 57.4	Braithwaite - 60.9
Northeastern - 53.9	Espanola - 58.1	Kirkland Lake - 64.4	Black Sturgeon - 45.5
Algonquin - 53.9	Sudbury - 37.1	Timmins - 42.0	Burchell Lake - 49.7
	North Bay - 60.9	Gogama - 71.4	
	Temagami - 68.6	Chapleau - 56.7	

[a] Source of data: Ontario Forest Resources Inventory.

further contrast can be drawn with the balsam harvest of 556,488 cu. m for that year. It should be remembered that the loss figures in Table 6 are for balsam fir mortality only. To these should be added mortality of white spruce and black spruce and growth losses of all three species. A conservative estimate of accumulated total loss to date would likely exceed 55 million cu. m. Even if the outbreak ceases shortly, tree mortality will continue for several years and the losses will increase.

Table 6. Areas of defoliation and tree mortality, and volumes of balsam fir killed by spruce budworm in northeastern Ontario, 1967-1980.

Year	Area of moderate-to-severe defoliation (ha)	Area of mortality (ha)	Balsam fir mortality (cu. m)
1967	25,900[a]		
1968	202,347		
1969	667,746		
1970	2,104,411		
1971	3,480,372		
1972	5,422,906	80,939	141,600
1973	5,058,681	202,347	198,240
1974	7,486,847	667,746	608,880
1975	11,007,689	1,214,083	1,146,960
1976	14,042,898	2,630,514	2,548,300
1977	13,468,231	4,168,353	4,361,280
1978	14,789,543	4,734,925	5,664,000
1979	16,939,972	6,110,886	7,249,920
1980	17,119,384	6,839,336	7,476,480
		Total:	29,396,160

[a] Light defoliation

What do these losses mean? Are there wood supply problems in northeastern Ontario at the present time? Will there be shortages in the future? The answer depends in part on the overall situation in terms of supply and demand, both now and in the future. If requirements are in balance with supply or if needs exceed supply, then losses of the magnitude of those which are being incurred in northeastern Ontario can only accentuate the problem. And undoubtedly in some situations, the loss of balsam and spruce on the scale described would cause severe supply problems for some industries that are dependent on supplies of raw material from relatively small forest areas with high volumes of balsam and spruce. The presence of growing budworm infestations in the North Central and Northwestern regions raises the spectre of a situation, perhaps 10 years hence, similar to the current situation in northeastern Ontario.

Can losses such as those described be prevented? On the one hand, the futility of attempting to deal with the current situation in northeastern Ontario on an overall basis seems apparent, because of the sheer magnitude of the problem. On the other hand, it may be possible under the right conditions to eliminate an incipient outbreak (epicentre) or prevent a growing infestation from spreading. The control actions west of Thunder Bay in the late 1960s and early 1970s come to mind. Various approaches to a solution of the budworm problem in eastern Canada have been proposed and many of them can be applied to Ontario. Undoubtedly, the ideal management approach is prevention, which can be accomplished by creating "budworm-proof" or "resistant" forests. It would be necessary to emphasize forest management practices leading to stand conversion by regenerating or favoring less susceptible coniferous species, appropriate mixtures of hardwoods and softwoods, full utilization of balsam fir on a short rotation, and diversification of age classes to prevent development of even-aged susceptible forests over large areas. However, it should be noted that these recommendations were first offered more than 60 years ago. There has been little deliberate attempt to implement them in the intervening years: witness two massive outbreaks since the 1920s. In any event, it will require intensive management to reduce the spruce-fir component significantly or alter the species composition of Ontario's forests. Any attempt to achieve this goal of resistant forests would, of course, require a long-term commitment of sufficient resources.

In terms of control or prevention, the foregoing has perhaps been more philosophical than practical. However, faced with the present situation, the forest manager has few options. He can harvest, salvage, spray or do nothing. All four options have been or are being practised in Ontario and will likely continue to be the management tools for the near future. Spraying is mentioned here only to emphasize that it is a management tool which the resource manager should consider, depending on the circumstances. It should be noted that a policy for spruce budworm spraying in Ontario has been developed recently: Policy/Procedure TM 13-04. The policy establishes that the Ministry may conduct spraying programs against budworm for a variety of purposes and provides guidelines for the selective protection of certain forests during the current outbreak.

The forest tent caterpillar is an insect that erupts periodically in Ontario, rising to high population levels and defoliating extensive areas. Its principal host in Ontario is poplar (*Populus* spp.), particularly trembling aspen (*P. tremuloides* Michx.), although in southern Ontario the insect also feeds on sugar maple (*Acer saccharum* Marsh.) and oak (*Quercus* spp.). In July, light brown moths deposit egg bands on twigs of host trees. The following spring, usually early in May, tiny larvae emerge from the eggs and feed on the new foliage. When full grown, usually by mid-June, the larvae wander a great deal. When feeding is completed they spin silken cocoons and change to moths in about 2 weeks. Outbreaks occur at intervals averaging about 10 years and, in the past, have infested areas of up to 26 million ha in Ontario. High populations persist, usually for 2-4 years, but sometimes longer. Outbreaks collapse rapidly, usually in a year or two, as a result of natural factors such as spring frosts, larval starvation, parasites and diseases.

Recent outbreaks in Ontario include one which lasted from 1948 to 1955 and reached 26 million ha at its peak, one which lasted from 1961 to 1967 and extended over 10 million ha, and the latest which began in 1975 and infested nearly 20 million ha in 1977.

In the face of high populations, much or all of the aspen foliage may be consumed by early or mid-June. However, injury to trees is less severe than might be expected because of the ability of aspen to refoliate. Apparently, some tree mortality is a result of repeated, severe defoliation by forest tent caterpillar but, over all, mortality is regarded as insignificant. Hence, the major consequence of repeated annual defoliation is increment loss ranging from 20 to 90% annually for the period during which defoliation occurs and for a year or two afterward.

Poplar is one of the major species in Ontario (Tables 1, 2 and 3) comprising about 18% of the total volume of wood. It is also an underutilized species in that the annual volume of poplar cut from Crown lands in recent years represents about 6 or 7% of the total cut of all species. The actual cut of poplar in 1973-1974 was about 15% of the allowable cut although it is recognized that depletion may be much higher.

The growth loss in aspen as a result of forest tent caterpillar defoliation, calculated for the year 1976 when 8.1 million ha were defoliated in Ontario, was some 3.68 million cu. m. Some 20 million cu. m of accumulated volume loss of poplar (increment loss) have probably resulted from the outbreak between 1975 and 1980. Another major impact of forest tent caterpillar outbreaks is the nuisance created by high larval populations (and the unsightly appearance of defoliated trees) in inhabited areas or woodlands used for recreation.

The forest tent caterpillar can be rather easily controlled over limited areas by spraying. Aerial or ground spraying of chemical and biological insecticides has proved to be highly effective. In Ontario, spraying has been conducted against forest tent caterpillar in recent years. However, control activity has been confined largely to provincial parks in southern Ontario for the purpose of reducing larval populations to prevent severe nuisance in campgrounds. There would appear to be little justification at the present time, at least on economic grounds, for aerial control operations in Ontario to prevent or minimize increment loss and occasional tree mortality in the poplar resource as a result of forest tent caterpillar defoliation.

The large aspen tortrix is the second major defoliator of aspen in Ontario. Trembling aspen is the major host but it will feed on white birch, balsam poplar (*Populus balsamifera* L.), largetooth aspen (*P. grandidentata* Michx.), willows (*Salix* spp.), alders (*Alnus* spp.) and choke cherry (*Prunus virginiana* L.) during epidemics. This insect overwinters as a young larva within hibernacula in protected places on branches or at the base of host trees. The young larvae emerge in the spring, usually early May, and mine developing buds. As the buds open and the leaf cluster forms, the larvae roll leaves and feed within the enclosures. Most of the defoliation occurs during this stage of larval development. Pupation takes place within rolled leaves from early June to mid-June and moths emerge 10 to 14 days later. Eggs are deposited from mid-June to early July on leaves or the main stem of host trees. Eggs hatch in a few days and the young larvae feed on leaf tissue until August when they prepare for hibernation.

Outbreaks of this insect in Ontario have been reported as follows: 1912, vicinity of Toronto; 1943-1946, vicinity of Sault Ste. Marie and Thunder Bay; 1956-1958, large outbreak in north central and northwestern Ontario; 1969-1975, northern Ontario where a maximum area of 13 million ha was affected. Infestations occur for 2 or 3 years in a given location, then collapse rather abruptly.

As with forest tent caterpillar, tree mortality does not seem to be a major consequence of infestations of large aspen tortrix. Increment loss is the major impact. As a result of the most recent outbreak in Ontario, aspen growth loss has been calculated at some 11 to 14 million cu. m.

In relation to the forest tent caterpillar, there would seem to be even less economic justification for controlling this insect or trying to prevent increment loss since infestations are short-lived and the main resource affected is aspen. Indeed, there have been no aerial spraying operations, that I am aware of, in Ontario, or, for that matter, anywhere else in Canada. Spraying campgrounds for aesthetic purposes might be considered in the future.

The Forest Insect and Disease Survey Unit conducted a special study this past summer (1980) to assess the impact of insects and diseases on cone and seed production of black spruce in northern Ontario. Black spruce flowers and cones were collected in early June, and cones in late July and mid-September, from the Northern, North Central and Northwestern regions. The following remarks are based on observations of the collections and impressions gained from raw data. Further analysis is required. The samples collected in early June in budworm-infested areas had high proportions of flowers infested with spruce budworm and spruce coneworm, *Dioryctria reniculelloides* Mut. & Mun. Female flowers were more heavily infested than male, and there appeared to be little difference in the incidence of damage in terms of infested flowers between upland and lowland sites. In areas free of budworm infestation (such as most of the Northwestern Region) the number of insect-infested flowers were low.

The second set of samples collected in late July when budworm and coneworm had finished feeding showed that in some heavily budworm-infested areas high proportions of female flowers aborted and failed to become cones, presumably as a result of early feeding by lepidopterous larvae. The spruce cone maggot, *Hylemya anthracina* Czerny, was the commonest insect although many cones also showed evidence of budworm and coneworm feeding. In some locations, insects have prevented a large number of cones from developing properly and in certain cases where cones developed successfully, the potential seed production was greatly reduced.

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STEM DECAY AND ITS IMPLICATIONS FOR MANAGEMENT IN THE BOREAL MIXEDWOOD FOREST OF ONTARIO

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The major problems connected with the fungal deterioration of killed trees and stem decay in living trees of the boreal mixedwood species are discussed. Stem decay and deterioration are difficult to control except through silvicultural and management practices based on knowledge of their relationships and development.

Les principaux problèmes liés à la décomposition des arbres morts par les champignons et à la carie de la tige chez les arbres vivants de la forêt boréale mélangée sont examinés. La seule façon de lutter contre la carie de la tige et la décomposition consiste à employer des techniques d'aménagement et de sylviculture fondées sur la compréhension de leurs relations et de leur développement.

The term *stem decay* naturally brings to mind the discolored, rotted wood in the heartwood or central core of living trees which frequently appear perfectly healthy. However, I would first like to discuss another form of stem decay, that which attacks the outer stem wood and progresses radially inwards toward the pith. More commonly referred to as deterioration, this occurs in all trees once they die, and is particularly important following widespread mortality such as Ontario is currently experiencing because of the spruce budworm, and has experienced this summer from forest fires. As it can develop quite rapidly under certain circumstances, it is obviously an important consideration when salvage operations are contemplated. Both types of stem decay are caused by fungi, the majority of which belong to the class Basidiomycetes, but the fungi that attack heartwood in living trees are usually not the same as those that attack the outer wood of dead trees.

The quality of balsam fir (*Abies balsamea* L.) trees at the time they die following budworm defoliation is as good as it was when these trees were alive--perhaps better, according to those handling the logs, because they contain far less liquid resin. They soon become more brittle, however, and therefore are more subject to breakage during harvesting, particularly when certain mechanical harvesting machines such as Koehrings are used. They also begin to deteriorate. The initial deterioration in dead balsam stems is a firm, reddish-orange stain in the outer stem wood caused by a fungus transmitted by woodwasps. These insects are much more common in the Atlantic provinces than in Ontario, and so is the red stain. This is not a serious problem as far as pulping is concerned. The stain is followed by sap rot caused almost entirely by *Polyporus abietinus* Dicks. ex Fr. This fungus, whose small white fruiting bodies with purplish under-surfaces are generally abundant on dead trees, attacks dead trees by airborne spores. Much of this soft, outer, punky wood is lost in the debarking process, but any that gets through severely reduces the brightness and tear factors for sulphite, kraft, and mechanical pulps.

In studies carried out 20 to 30 years ago it was observed that budworm-killed balsam fir in Ontario developed *P. abietinus* sap rot very extensively one year after death, whereas in New Brunswick it took 3 or 4 years for sap rot to develop. We are now collecting evidence that this is in some way related to the population levels of the balsam fir bark beetle, a tiny insect that attacks the stems of balsam fir shortly after they die. This insect was very widespread on the killed trees in Ontario, but scarce in New Brunswick.

In 1977 we began a study of the effects of budworm-killed balsam fir stems, at different periods following death, on the yield and quality of pulp characteristics. Although the Pulp and Paper Research Institute in Vancouver has not yet released many pulping data from our material, we have found that where the bark beetles are very scarce, around Chapleau and Foleyet, sap rot is not much of a problem even 5 years after the trees have died, whereas in Whyte, Minnesota just south of Quetico Park, where bark beetle levels are very high, sap rot is quite extensive only 2 years after the trees have died (Tables 1 and 2).

With the increasing threat of spruce (*Picea* spp.) mortality as a result of budworm defoliation in Ontario, it is unfortunate that our only information on the rate of deterioration of budworm-killed spruce consists of some rather skimpy data from the Maritimes, and a thorough study carried out in the Gaspé region 45 years ago on spruce killed by insects other than the budworm. Our knowledge of the deterioration of fire-killed stands is based on a study on jack pine (*Pinus banksiana* Lamb.), red pine (*P. resinosa* Ait.) and white pine (*P. strobus* L.) killed in the Mississagi fire of 1948, and on a study of fire-killed spruce, balsam fir, and jack pine pulpwood stands carried out in Quebec in 1942.

Stem decay in living trees is often referred to as heart rot. This rot is generally caused by several Basidiomycete fungi in any one tree species, although generally there are two or three that cause over 90% of the damage. These fungi cannot penetrate intact, healthy bark, or healthy sapwood. They usually enter via dead, broken tops, dead branches and stubs, trunk wounds, or the root system. The last-mentioned avenue, the root system, is used almost exclusively by a certain group of fungi called root- or butt-rotting fungi. Their rot columns seldom extend higher than 1-1½ m above ground. This important disease and associated fungi will be discussed by Dr. Whitney in his paper.

Table 1. Secondary stem insect activity in killed balsam fir[a]

Region	No. of years dead	Woodwasps, oviposition holes plus exit holes	*Monochamus*, entrance holes plus exit holes	Bark beetles, nuptial chambers plus bark holes
Chapleau	0-1	0.11	0.1	0.1
Chapleau	1-2	0.03	0.2	0.2
Mattawa	0-1	0.02	0.2	5.0
Mattawa	1-2	0.08	0.2	4.4
Whyte	0-1	0.01	0.3	13.4
Whyte	1-2	0.02	0.2	8.5

[a] Expressed as number of holes, nuptial chambers per dm^2 of stem surface.

Table 2. Balsam fir dead 1-2 years.

		Percentage of total merchantable volume						
Region	Avg tree merchantable volume (m^3)	Sap stain	Sap rot			Total sap rot	Advanced and moderate sap rot	Total deterioration
			inc.	mod.	adv.			
Chapleau	.087	20.8	12.3	1.0	0.0	13.3	1.0	34.1
Mattawa	.091	11.7	10.9	11.7	3.8	26.4	15.5	38.1
Whyte	.062	7.1	10.7	14.9	5.2	31.0	20.1	38.1

Because stem decay is generally confined to the central core, or heartwood, of living trees, many pathologists considered the decay fungi to be saprophytes, not parasites. It has recently been emphasized, at a symposium on stem decay, that these pathologists overlooked the important point that parasitism is defined on the basis of interactions at the organism level, and that heartwood can contain living cells. Stem decay is a disease and the causal fungi are both pathogenic and parasitic.

In a recent review of factors responsible for wood losses in Ontario, stem decay heads the list with an estimated 5 million cu. m of fibre affected annually, while the spruce budworm is a close second. In 1958 the United States Forest Service published the Timber Resources Review, in which it appraised the impact of destructive agents on the United States timber supply. It showed that at that time losses from disease exceeded those caused by fire or insects, and that 73% of the disease loss was made up of decay in standing timber. Of course, it can be argued that these are not really losses until decayed trees are cut. In the early 1960s when I had completed a province-wide cull survey with John Morawski of what was then the Ontario Department of Lands and Forests, we attempted to place an actual value on this loss based on data provided in the Department's annual reports for 1960, 1961, and 1962. Using the average annual volume cut for each species, ages for each species arbitrarily selected to approximate average harvest ages, the average scaled losses due to stem decay at those particular ages, and the annual revenue from Crown stumpage charges by species and product, we calculated that about 623,000 cu. m of timber, roughly 6.3% of the annual cut in Ontario, was culled because of stem decay. This amounted to a loss of just under 1 million dollars annually in Crown revenue from stumpage charges, a considerable sum at the time. Actual losses due to stem decay are difficult to measure, such as reductions in product quality and value, decreased efficiency and extra costs in harvesting and mill operations, and so on. In any event, their widespread occurrence to some extent in all species makes stem decay a major forestry problem, particularly in the boreal mixedwood forest where the two species that are expected to increase in the future, balsam fir and trembling aspen (*Populus tremuloides* Michx.), are both relatively defective.

Among the various boreal mixedwood species, balsam fir is attacked by only one fungus causing stem decay, *Stereum sanguinolentum*, Alg. & Schw. ex Fr., which produces "red heart". Under certain conditions the decay can become quite severe, and is apt to make it economically hazardous to harvest stands older than 60 or 70 years. Its occurrence does not seem to be very closely related to site. It enters mainly by wounds in large living branches, and by dead, broken tops if these are of sufficient diameter. Like most stem decays, it is difficult to control other than by maintaining vigorous tree growth, avoiding stem and branch wounds, and harvesting before it reaches an age when a serious problem develops.

Trembling aspen, like balsam fir, can develop extensive stem decay at a relatively early age. At 100 years of age an average of close to 25% of its merchantable volume is in a state of decay, but it is wise to cut stands at 60 years to avoid the risk of serious decay losses and damage due to Hypoxylon canker, etc. The major cause of stem decay is *Fomes igniarius* (L. ex Fr.) Gill., which produces a creamy-yellow, spongy decay, often with irregular black zone lines. It appears to enter the stem mainly by branch stubs, and first shows up in stands 30 to 35 years of age. It is possible that the branching and self-pruning habits of certain aspen clones may make them either relatively resistant or susceptible to *F. igniarius* infection. Interclonal variation in both growth and decay resistance is one of several aspen quality subjects we are currently studying in cooperation with the Ontario Ministry of Natural Resources and American Can Canada Inc. Most of the fast-growing clones we have discovered also have above-average amounts of stem decay, although four or five so-called "superior" clones have been found. There are ways of managing aspen intensively to promote the establishment of superior clones, but these are relatively costly. The use of superior clones in plantations close to aspen-utilizing mills may be a more feasible short-term objective, to take advantage of the clonal growth habit of aspen.

Another study has been set up in response to concern that aspen sucker stands springing up over the past 30 years following harvesting operations might result in crop trees of lower quality than those in the original stands that were primarily of fire origin. To date, our results suggest no reason to expect much difference in quality, regardless of origin.

We are also studying the effects on aspen sucker quality of two treatments, herbicide spraying and scarification, used to eliminate or suppress aspen so as to enhance the development of planted conifers. Surviving suckers have been examined 7 and 9 years after spraying. No stem decay was found, and the limited amount of stain was virtually the same in extent as that found in untreated suckers of the same age. Furthermore, no harmful decay-causing Basidiomycetes could be isolated from these stains. Spraying will kill the leaders of aspen suckers, but it is normal for suckers to have leaders killed in most growing seasons, usually from late frosts or shoot blight disease. Therefore, it appears safe to predict that aspen suckers which survive spray damage, and most of them do, have the potential to produce good-quality crop trees (Table 3).

Table 3. Quality of herbicide-damaged aspen suckers.

Treatment	Year sampled	No. of suckers	Age	Years since spray	Avg ht base of dead leader (m)	Avg sucker volume inside bark (dm^3)	Avg volume rot	Avg volume stain (dm^3)	% of total volume stained
Sprayed	1976	80	12	7	1.44	1.70	trace	0.16	9.4
Sprayed	1978	80	14	9	1.23	3.11	trace	0.27	8.5
Control	1978	20	14	9	-	6.22	trace	0.32	5.2

We are also studying the effects on sucker quality of scarification undertaken to promote good aspen regeneration. These results have not yet been analyzed. Another study in an aspen sucker stand that was scarified when most suckers were 3 years old, in preparation for the planting of spruce, has revealed that severe stem wounds are still noticeable on surviving aspen 4 and 6 years after the treatment. These wounds were usually associated with abnormally extensive stain. The larger wounds, those not callused over, were frequently associated with decay pockets. Unscarified control suckers had no decay, and contained far less stain from which harmless organisms were isolated. A number of the scarified stems, on the other hand, were colonized by Basidiomycete fungi, including those known to cause stem decay in mature aspen. All suckers sampled were dominants or co-dominants. Hence, it appears that scarifying 3-year-old aspen suckers could have a serious impact on the quality of the survivors that will eventually become crop trees (Table 4).

Table 4. Quality of 9-year-old aspen suckers 6 years after scarification.

Condition/location of suckers	No.	Avg sucker volume (dm^3)	% of inside-bark volume		
			Stain	Rot	Total defect
Unscarified patch within stand	10	3.10	11.2	trace	11.2
No visible stem wounds	21	1.30	12.6	trace	12.6
Stem wounds callused over	14	1.32	18.3	0.4	18.7
Stem wounds open, <.25 cm	12	1.38	22.3	2.4	24.7
Stem wounds open, >.25 cm	13	1.03	33.4	6.3	39.7

The results obtained from analyzing the root systems of aspen suckers and trees for root rot and other defects will be discussed in Dr. Whitney's paper.

White spruce (*Picea glauca* [Moench] Voss) is somewhat more susceptible to stem decay than black spruce (*P. mariana* [Mill.] B.S.P.), although both are relatively sound species. Butt rots are more important, even on a volume basis, than stem decays. One fungus, *Fomes pini* (Thore) Lloyd, causes most trunk decay, but is hardly ever a serious problem in these species. Its decay is characterized by pockets of almost pure white cellulose fibres surrounded by softened, reddish wood. White spruce older than 100 years have, on the average, 3% of their merchantable volume decayed. Black spruce reaches a peak of roughly 3.5% at age class 121-140, then differs from all other species in that as stand age increases, the percentage of volume decayed actually decreases. This is attributed to the gradual removal by windfall or mortality of the more decadent trees, and to the fact that the older age classes are mainly on moist or wet sites which generally have less decay than fresh or dry sites. Faster growing black spruce trees tend to be more susceptible to stem and butt decay regardless of site. This suggests that management procedures to accelerate the growth rate of black spruce could be accompanied by a significant increase in the incidence of stem decay.

Little is known about stem decay in white birch (*Betula papyrifera* Marsh.), although we did fell and examine 936 trees in the province-wide cull survey I referred to earlier. As in the case of aspen, *Fomes igniarius* causes most of the stem decay in this species, which averages only about 5% of the merchantable volume in trees 100 years old. Site had little effect; however, trees on drier sites tended to have the least stem decay.

Jack pine occurs infrequently in the boreal mixedwood forest, as this forest was defined in the first paper of the Symposium. Nevertheless, some interesting relationships concerning stem decay, site, and growth rate in this species justify a few words here. Most stem decay is caused by *Fomes pini*, which can be very extensive in stands older than 80 years on the dry sand plains where jack pine is most commonly found. However, in the cull survey we examined about 500 jack pine on moderately fresh sites, moisture regimes 2 or 3, which fall within our definition of boreal mixedwoods. These trees had a distinctly faster average growth rate, and significantly less stem decay, than the 3,600 trees we examined on dry sites with moisture regimes 0 and 1. Moisture regimes 2 and 3, within the boreal mixedwood forest, may well represent close to the optimum sites for jack pine quality, and perhaps for growth rate as well. Although jack pine is more difficult to establish and maintain on these sites than on dry sites, the advantages in both growth rate and lower incidence of stem decay suggest that it could be well worth considering as a management alternative.

ROOT ROT AND ITS IMPLICATIONS FOR MANAGEMENT IN THE BOREAL MIXEDWOOD FOREST

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Wherever windfall occurs root-rotted trees are the first to blow over. Butt cull, growth reduction and outright mortality are also attributable to root rot. In trees examined in Ontario's boreal mixedwood forest, root rot losses at 70 years of age averaged 33, 33 and 20% of gross merchantable volume in balsam fir (Abies balsamea *[L.] Mill.), black spruce* (Picea mariana *[Mill.] B.S.P.), and white spruce* [P. glauca *[Moench] Voss), respectively.* Armillaria mellea *is by far the most important root rot parasite in both merchantable and younger trees.*

Les arbres pourris à la racine sont les premiers à être déracinés par le vent. La maladie est également responsable des gros bouts inutilisables, de la réduction de croissance et de la mortalité des arbres. L'examen des arbres dans la forêt boréale mélangée de l'Ontario a révélé que le Pourridié avait causé des pertes moyennes de 33, 33 et 20% du volume marchand brut respectivement chez le Sapin baumier (Abies balsamea *[L.] Mill.), l'Épinette noire* [Picea mariana *[Mill.] B.S.P.), et l'Épinette blanche* [P. glauca *[Moench] Voss) à l'âge de 70 ans.* Armillaria mellea *est de loin le plus important des parasites responsables du Pourridié, tant chez les arbres commercialisables que chez les plus jeunes.*

My remarks on root rot will refer chiefly to the three conifer species of the boreal mixedwood forest on which I have worked for the last nine years in Ontario, black spruce (*Picea mariana* [Mill.] B.S.P.), white spruce (*P. glauca* [Moench] Voss), and balsam fir (*Abies balsamea* [L.] Mill.). Root rot of trembling aspen (*Populus tremuloides* Michx.) will be discussed later on the basis of data supplied by J.T. Basham.

Root rot in the three conifers is caused by some 30 species of fungi, six or seven of which cause the bulk of the rot (Whitney 1978). Of these important species, *Armillaria mellea* (Vahl ex Fr.) Kumm., the common shoestring mushroom, can be singled out as the number one problem.

In more than 120 stands, mostly 30 to 100 years of age, sampled in the boreal forest from Sioux Lookout in the west to Iroquois Falls in the east, root rot was invariably found to some degree in spruce and balsam fir (Whitney 1976). Simply to demonstrate the presence of root rot and its severity in various species and age classes is of little use to a forest manager unless it can be shown that it is possible to save some wood or increase growth rates. For this reason I have quantified the various kinds of root rot damage in various age classes and have attempted to uncover relationships between damage and tree age, and between damage and site types.

There are four types of root rot damage in trees more than 30 years of age. *Outright mortality* occurs when the fungi attack the roots and eventually girdle all of the primary buttress roots and/or the base of the tree. This may take many years after the first invasion of the root system. It occurs in dominant, vigorous trees, but is more common in slow-growing suppressed trees. *Premature windfall* occurs when the structure of the roots and lower stem is weakened by the decay processes of root-rotting fungi so that trees which would normally withstand the stresses of heavy winds are felled even by winds of moderate strength. *Butt cull* results from the extension of wood decay by root-rotting fungi into the merchantable butt portion of the tree. This cull is in the most valuable part of the tree and may increase transportation costs per unit volume of usable wood if it is transported in tree lengths to landings or even to the mill before being butted off. Some fungi cause much more butt cull than others by extending several cm up the stem. Fortunately, *Armillaria mellea*, though widespread, is confined largely to below-stump parts of the tree. *Reduced increment* is the result of slower growth rate when the flow of water and nutrients through the vital tissues is disrupted. This disruption of the water- and nutrient-conducting system can continue for 15 or 20 years, but eventually the tree will die.

Often trees are harvested before they die but are smaller than if they had remained free from heavy root rot. It has been found that about 60% or more of the roots must be killed for a slowdown in growth to occur. Some species of root-rotting fungi are more capable of this kind of damage than others, i.e., some species are confined to the "dead heartwood" of roots and lower stem, while others attack the living tissues and disrupt vital processes.

Losses from dead and windfallen trees are considered together since, for the most part, they both result in unusable trees by present utilization standards. Dead and windfallen trees resulting from root rot, unlike trees in areas where there have been large fires, massive blowdowns or spruce budworm epidemics, are usually scattered and in various stages of deterioration. However, the losses from root rot, unlike those resulting from the aforementioned catastrophes, are continuous rather than periodic, and are increasing year after year. Losses over a period of years can therefore be predicted with reasonable accuracy on the basis of average losses in stands of comparable age and on similar sites that have been sampled across the boreal forest. These measurements indicate that in the boreal mixedwood forest, stands of balsam fir, black spruce, and white spruce averaging 70 years of age have average volumes of 17%, 12% and 7%, respectively, in the form of dead and windfallen crop (dominant and codominant) trees. Loss figures are much higher in older trees, averaging 26%, 20% and 17%, respectively, in the three species at 100 years of age; in younger trees they average 10%, 6% and 3%, respectively, at 50 years of age.

In a preliminary analysis of trees sampled in northwestern Ontario, butt cull due to root rot averaged 6%, 8% and 8%, respectively, of gross merchantable volume at 70 years of age in the remaining living crop trees, and growth increment lost as a result of heavy root rot averaged an additional 10%, 12% and 5%. When losses from all these types of damage are totalled, we find that, for the three species, they amount to 33%, 33% and 20%, respectively, of gross merchantable volume per unit area at age 70. This is about one quarter of the wood volume in dominant and codominant trees of these three species, and the proportion of wood lost to root rot increases rapidly with increasing tree age.

There are rather large differences in root rot losses among sample areas. Some areas such as Longlac and Geraldton had lighter than average root rot, but sample plots in these two areas were in stands that were younger than average. Root rot losses were heavy for all three species in the Spruce River Road area (north of Thunder Bay), but were comparatively light in Hearst and Cochrane in stands of similar age (80 yr). For the three species, average volume losses in potential crop trees as a result of mortality, windfall and butt cull were 24.6% at Spruce River Road compared with 13.9% at Hearst and only 9.8% at Cochrane. These differences are due largely to site as will be explained later. Limited sampling indicates that root rot losses in the Great Lakes-St. Lawrence Forest Region may be higher than those in the Boreal Forest Region. Root rot volume losses due to mortality, windfall and butt cull in the three species on 12 plots in the Great Lakes-St. Lawrence Forest Region averaged 27.6%; in the Boreal Forest Region they averaged 14.4%. The reasons for this large difference are not obvious.

That root rot as evidenced in butt cull is more severe in upland than in lowland black spruce is known to most foresters. Many root-rotting fungi grow better in the better drained, more fully aerated upland soils, just as the trees do. Therefore, trees on the better drained sites with lower moisture regimes have more extensive root rot than those of the same age on less well drained sites with higher moisture regimes (Whitney 1976, 1978). Undoubtedly, the higher moisture regimes on the fine-textured, poorly drained soils in the Hearst and Cochrane areas account for the fact that there is less root rot there than in the north central and northwestern regions of northern Ontario.

Since direct control with chemicals or biological control agents is impractical with diseases that are not only inside the tree but also mostly below ground, stand manipulation through silvicultural application is the chief means of control. In the natural stands in which there has been no investment in growing timber, dead trees or windfallen trees cannot be considered losses. Had they remained living and standing the cost per unit volume of delivered wood to the mill would be somewhat lower, but I suspect that the main concern is the nuisance this material poses to loggers. Future losses of this kind will be real, however, where investments have been made in regeneration and stand treatments. Similarly, lost increment is not really a loss where no investment has been made, and delivered wood from natural stands is probably only fractionally more expensive because the timber is somewhat smaller as a result of root rot.

Butt cull, on the other hand, constitutes a real loss because, as soon as the tree is felled, there is an investment in it. If the rotted wood is transported to the landing or mill prior to butting, the loss is still larger because there is an even greater investment in the log after it has been transported. The greatest loss from reduced increment in natural stands, whether this loss is due to root rot or any other factor, is probably the decrease in product value because the tree is smaller at rotation age. If potential sawlog trees do not reach sawlog size by rotation age and consequently must be harvested for pulpwood, the difference in value per unit of wood volume received must be charged against the agent which prevented the tree from reaching its potential sawlog size.

The following are a few precautions that can be taken to reduce root rot losses in spruce and fir stands above 30 years.

1. Leave the butt rot at the stump.

2. Within the bounds of other uncontrollable factors, cut first those trees which are on sites most susceptible to root rot, i.e., those on better drained, lighter textured soils with lower moisture regimes.

3. Whenever possible, where stands of similar ages are concerned, harvest the most susceptible species (i.e., balsam fir) first and the least susceptible species (i.e., white spruce) last.

Spruce and balsam fir stands less than 30 years of age also suffer from root rot. The main type of damage in young stands is mortality. Not enough is known about root rot losses in our young stands, but more than 2% mortality of young conifers was reported in northern Ontario in 1976 (Sippell et al. 1976). Recent data gathered by the author showed that mortality associated with *Armillaria mellea* ranged from 0.5% to 13%, with an average of 4%, in six black spruce and eight white spruce plantations averaging 12 years of age in northern Ontario (Table 1). The following subject areas require study.

1) accumulated losses over a period of years on various sites, and spatial distribution of surviving trees

2) the possible development of resistance as trees mature

3) the possible genetic basis for resistance.

Table 1. *Armillaria mellea*-related mortality of spruce in northern Ontario plantations.

	Species	Planted (yr)	Mortality (%)
1975			
Petawawa	Black spruce	1967	13.0
1978			
Limestone Lake No. 1	White spruce	1967	3.2
Limestone Lake No. 2	White spruce	1967	3.2
Casgrain Twp	White spruce	1967	2.5
Manning Twp	White spruce	1970	1.5
1980			
Elsie Lake Rd. No. 2	White spruce	1972	6.2
Elsie Lake Rd. No. 3	Black spruce	1972	6.9
Elsie Lake Rd. No. 4	Black spruce	1972	5.4
Kenshoe Lake No. 1	White spruce	1960	2.5
Kenshoe Lake No. 2	White spruce	1960	0.5
	Black spruce	1960	1.2
Ylo Lake	White spruce	1969	1.4
Cupa Lake	Black spruce	1968	2.7
Budd Lake	Black spruce	1973	5.8
	Average		4.0

Roots of herbicide-killed oak (*Quercus* spp.) competition infected with *Armillaria mellea* were demonstrated to be the inoculum source for young red pine (*Pinus resinosa* Ait.) killed by *A. mellea* in Wisconsin (Pronos and Patton 1977). Although there is no proof, it is strongly suspected that the accumulation of *A. mellea* in roots of herbicide-killed hardwoods in Ontario results in the spread of this fungus to the released conifers and contributes to mortality caused by *A. mellea*. Mycelial fans, rhizomorphs, and yellow stringy decay of *A. mellea* have been found in abundance in Ontario in roots of herbicide-killed trees of the following species: trembling aspen, white birch (*Betula papyrifera* Marsh.), black ash (*Fraxinus nigra* Marsh.), mountain maple (*Acer spicatum* Lam.), and speckled alder (*Alnus rugosa* [Du Roi] Spreng. var. *americana* [Regel] Fern.). The proximity of *A. mellea*-killed black spruce and white spruce roots to infected roots of aspen and alder strongly suggests that roots of the latter two species served as inoculum sources for the killed conifers.

To reduce losses due to *A. mellea* in young stands, it is essential to minimize the effective inoculum. Before investigating ways of reducing this inoculum, however, we must have a better understanding of losses in young conifer stands attributable to this fungus and of the sources and nature of inoculum leading to infection.

Root rot of trembling aspen has been studied by Basham in trees ranging from 7 to 45 years of age on cutover areas north of Manitouwadge in north central Ontario and in the Fort Frances area of northwestern Ontario. Basham found that 60% of the aspen suckers in untreated stands 7 to 9 years old had some degree of root rot, while 97% of those 29 and 45 years old had root rot. Suckers 7-9 years old that had been subjected to scarification were more heavily attacked (83%) by root-rotting fungi, as was expected, while herbicide spraying resulted in no increase in root rot in suckers 12 to 14 years old. As with spruce and balsam fir in northern Ontario, the main root-rotting fungus in aspen is *Armillaria mellea*. Roots of over one third of the aspen suckers 7 to 14 years old have tunnels by larvae of the ghost moth (*Sthenopis quadriguttatus* Grt.). The significance of this insect damage has not been determined.

It may be concluded from Basham's results that scarification, commonly carried out on cutover stands, increases the incidence of root rot in young aspen suckers 7 to 9 years old. Even though the two older untreated stands that were investigated displayed a very high incidence of root rot by ages 29 and 45, it seems obvious that scarification would increase the levels of root rot in the maturing stand. How much this root rot contributes to mortality, windthrow and increment loss in aspen has not been ascertained. Surviving aspen will no doubt be harvested in many stands where earlier scarification was carried out in an attempt to reduce its presence, and there is little doubt also that the early damage to roots and lower stems in the young trees will contribute to root and butt rot defects as the stand matures. The resultant losses have yet to be quantified.

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OTHER IMPORTANT DISEASES ASSOCIATED WITH THE BOREAL MIXEDWOOD FOREST

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Except for root and stem rots, few diseases have a major impact on the boreal mixedwood forest, although some, such as spruce needle rust, ink spot of aspen, mistletoe and aspen shoot blight, are important in specific situations. Hypoxylon canker seems to limit aspen culture to short rotations, while birch dieback has caused extensive damage to white and yellow birch.

Hormis le Pourridié et la carie de la tige, peu de maladies nuisent véritablement à la forêt boréale mélangée, bien que certaines comme la Rouille des aiguilles de l'Épinette, la tache d'encre du Peuplier faux-tremble, le Faux-Gui et la brûlure des pousses du Peuplier faux-tremble soient non négligeables dans certaines situations. Le chancre hypoxylonien semble limiter la culture de Peuplier faux-tremble à de courtes rotations, tandis que la mort en cime cause de graves dommages au Bouleau jaune et au Bouleau à papier.

The previous papers by Whitney and Basham demonstrated that stem and root decays must be given considerable attention in the management of the boreal mixedwood forest. The present paper attempts to describe other diseases which have an important affect on this forest. Importance, as I see it, frequently depends on perspective. Aspen (*Populus* spp.) rotation age is extended and height growth is reduced by aspen shoot blight (*Venturia macularis* [Fr.] E. Müller & von Arx). On the other hand, the blight serves to reduce broad-leaved competition to conifers.

As I present this paper, I sense that attitudes toward this forest type are changing rapidly. Optimization of spruce (*Picea* spp.) production continues to occupy our thinking, for spruce is our most valuable timber species. However, we are beginning to consider the accommodation and utilization of other species. Attempts in the past to reduce or exclude these other species by scarification, burning, slashing, and herbicide application have not been a resounding success. Moreover, these practices are expensive. Inasmuch as current management practice seems to favor regeneration to species that compete with spruce, our dollars might be better spent managing these species.

I believe that complete utilization of the boreal mixedwood forest is the answer to many disease and silvicultural problems. For eons this forest managed itself as well as, or better than, man has. Our attempts to dominate nature have consistently fallen short of acceptable economic and silvicultural goals. On the other hand, we are frequently successful when we build upon elements of the natural system which favor our goals. A period of site occupation by pioneers like aspen, birch (*Betula* spp.) and possibly balsam fir (*Abies balsamea* [L.] Mill.) probably favors a climax species like spruce. Accepting and utilizing these pioneers may be necessary if we want to optimize spruce production. Certainly utilization will minimize the impact of disease on all of these species, including spruce. I have decided, therefore, that all species in the mixedwood forest are important from a management point of view.

I had some difficulty deciding which diseases to discuss in this paper. With some justification cochairman Whitney urged me to include frost. Certainly in 1979 and 1980 frost had a major impact on the mixedwood forest, particularly spruce and balsam fir. Forest Insect and Disease Survey (FIDS) field technicians surveyed white spruce (*Picea glauca* [Moench] Voss) plantations in 1979 and found that frost was the principal cause of foliar damage. Other abiotic agents also cause damage. Herbicides applied to reduce broad-leaved competition frequently form a food base for Armillaria root rot and thus increase its potential to kill conifers. Reactions to damage caused by harvesting machinery and burning, adverse site reaction, and simply poor species selection for certain sites also cause problems that could be interpreted as disease. There could well be a forest pest sitting next to you.

I will deal with the various diseases I have chosen to consider in an order relative to the stand size most affected. A few diseases are mentioned because they look spectacular or are important in other timber types. For the most part, however, the diseases I will discuss can have a significant influence at some period of stand development.

Cone rust caused by *Chrysomyxa pirolata* Wint. has been prevalent in some years, and could be a problem in seed orchard management. In 1967 spruce cone infection was common in the North Central and Northwestern regions. In some places over 80% of the cones were diseased. This year seems to be typical of most years. Only two or three collections of cone rust were detected--fewer than I had expected in view of the fact that we are conducting a survey of spruce cone and seed pests. Control is impracticable. Data for predicting epidemics are lacking and eradication of the pyrola alternate host would be difficult if not impossible.

Aspen shoot blight commonly kills back the terminal growth of trembling aspen (*Populus tremuloides* Michx.) and, to a lesser extent, largetooth aspen (*P. grandidentata* Michx.). Infection causes succulent leaf and twig portions to wither and turn black. New shoots frequently sprout adjacent to these killed twigs. The new shoots occur in close proximity to a source of inoculum, and many of these also become infected. Studies conducted in the American Can Canada Inc. limits near Manitouwadge indicate that terminals are especially susceptible to infection. The stands most affected had trees with an average height of less than 3 m. Stands with trees over 5 m in height had only negligible damage.

Impact on newly emerging sucker stands was devastating. These suckers have a single stem, and usually about half of it is killed. In 1978 and 1980 stands this size with virtually all of the terminals killed were common in parts of Ontario. The blight can kill small trees, but usually only tree form and height growth are affected. Prolonged wet weather favors infection, and FIDS records indicate that infection has been common in about 5 of the last 10 years. Data analysis for the Manitouwadge study is not complete; however, shoot blight apparently retarded growth to the extent that trees of sucker size lost about 20-25% of normal terminal growth for the years 1968-1977.

Fungicides can control most diseases, but their application is not feasible in natural stands. The source of infection is the dead debris of previous infections. Patchy patterns of infected trees in young sucker stands seem to indicate that the initial source of inoculum is outside the affected stand. Thus far neither the disease nor the host have been considered important enough to stimulate research into control methods.

Rhizina root disease caused by *Rhizina undulata* Fr. is probably an important cause of conifer seedling mortality in recently burned areas. The disease seems to be restricted to fire sites, possibly because the spores that cause infection are stimulated to germinate by heat (50°C). Last year our FIDS field technicians checked a selection of 25 natural or prescribed burn sites and detected Rhizina on five of the sites. Also, members of our fire research group at the Great Lakes Forest Research Centre commonly find Rhizina fruiting in the burns they investigate.

The fungus appears to be a weak parasite that can compete only where fire has more or less purged the area of competition. Both mortality and fruiting were investigated at several locations in British Columbia. Seedlings were killed in groups, and 10% seedling mortality was attributed to Rhizina root rot. After two years, impact was negligible. Reports from Europe indicate that the disease can spread into mature timber and cause stand openings. This has not been observed in Canada. Limited data for Ontario indicate that we probably have a problem similar to that of British Columbia. Fallowing a site for two years after a burn probably can provide control. For Ontario we hope to provide data on the type of sites likely to be inhabited by Rhizina.

Spruce needle rust caused by *Chrysomya ledi* d By and *Chrysomyxa ledicola* Lagh. can affect spruce of all sizes. In 1969 spruce suffered severe foliar damage (>75% killed) near Nipigon and Long Lac (10,000 ha). Damage was easily detected and mapped from the air as entire trees appeared orange because of the rust pustules. Usually the rust is confined to understory trees and the lower branches of larger trees.

Control does not seem necessary or practical. The alternate hosts, Labrador tea and leather leaf, are ubiquitous in most spruce stands and would be almost impossible to eradicate. Genetic selection may be possible as some trees seem to escape infection in mild infestations; however, severe infestations seem to affect all trees. In any case, the occasional occurrence does not seem to be enough to warrant control.

Fir needle rust caused by *Pucciniastrum epilobii* Otth., a problem similar to spruce needle rust, rarely occurs at damaging levels.

Ink spot of aspen caused by *Ciborinia whetzelii* (Seaver) Seaver can also be impressive. Diseased foliage turns bright reddish brown and develops hard black splotches from which the common name evolved. The fungus overwinters in these black patches. As is the case with many foliar diseases, the amount of damage sustained depends largely on the weather. Wet seasons favor ink spot.

Again, control does not seem to be warranted as aspen is not a particularly valuable species. However, genetic selection does seem possible. Aerial photos taken last year indicate a range in resistance among aspen clones. If this is a fact, resistant clones could be favored.

Dwarf mistletoe is caused by *Arceuthobium pusillum* Pk. Surveys conducted in 1973 indicate that mistletoe of spruce is a problem mainly on lowland sites and in adjacent areas. Hence, it is not a problem in the boreal mixedwood forest.

Broom rusts of fir caused by *Melampsorella caryophyllacearum* Schroet., and of spruce caused by *Chrysomyxa arctostaphyli* Diet. have negligible impact. Survey records include a few instances of moderate damage, but these seem to be special situations. Individual trees can have brooms over 1 m^2 in size, and then tree vigor does seem reduced.

Hypoxylon canker caused by *Hypoxylon mammatum* (Wahl.) Miller, together with stem decay, seems to limit aspen to a rotation age of 60 years. Cankered trees frequently suffer wind snap, and cankers often girdle large stems in less than five years. In the natural system, breakup of aspen stands by canker and rots favors the conifers usually present in the understory. Utilization without the destruction of conifer regeneration should have the same effect. Insect wounds caused by *Saperda* sp. and small branch breaks provide most of the infection sites.

FIDS field technicians surveyed aspen stands for Hypoxylon canker in 1973. In about half of the stands sampled over 25% of the trees had stem cankers. Annual mortality in these stands averaged 7%. By contrast, field technicians sampled only aspen sucker stands in 1977, and found few cankers in these young stands. Most stands (85%) were unaffected, one stand had 3% of its trees cankered and the remainder had fewer than 1% cankers. It is apparent that the incidence of Hypoxylon canker increases as stands age, and cankering is the principal cause of mortality in overmature stands.

Harvesting before Hypoxylon becomes a serious problem seems to be the best control measure. Impact is usually negligible for well stocked stands which have a site index of 2 or better, and are less than 40 years of age. Disease incidence seems to be related to stand density. Impact potential is greater on understocked sites where the losses are less tolerable.

Birch dieback is destined to remain a mystery. No doubt a lot of white birch (*Betula papyrifera* Marsh.) and yellow birch (*B. alleghaniensis* Britt.) died throughout eastern Canada in the 1950s as a result of a complex of pest agents. However, no one could agree on the cause of this dieback. White birch seems to suffer from dieback as stands become overmature, and this condition, too, is frequently called birch dieback. The presence of this dieback seems to favor conifer content for the next stand; hence, the dieback of white birch that is due to maturity is really an asset. A variety of fungi appear to be capable of causing branch cankers as aging reduces tree vigor.

Discussion

J.K. Jeglum: I'd like to ask Ago Lehela a question. For the mixedwoods that have been harvested--cleaned out of their conifer component--what are the possibilities for herbicide treatment of those large residual trees?

A. Lehela: At present the Ministry of Natural Resources does not have a herbicide that is aerially applied to remove both residual hardwoods and residual conifers from mixedwood sites. 2,4-D will remove the birch and some of the poplar. Addition of fuel oil to the 2,4-D spray mixture will enhance the killing of some conifers. Two new herbicides--glyphosate (Roundup®) and Velpar®--which are not yet registered for aerial application in Ontario, look promising to replace 2,4,5-T which is no longer available. Both herbicides will kill birch and poplar but not established conifers such as balsam fir and spruce.

D.E. Ketcheson: I'd like to ask Henry, Roy or Jack what the possibilities are for biological control of aspen or other unwanted species, using decay or insects as release agents for conifer understory?

R.D. Whitney: As far as diseases are concerned, the only experimental work I know of is that by Dr. R.E. Wall in New Brunswick on the black knot disease of cherry species, and on bacterial blight as a control for raspberries. Preliminary results indicate some possibilities for control of pin cherry. This would seem like a fruitful area for investigation, but I think we should stick with native diseases.

G. Brown: I'd like to have a crack at this. I'd like to answer Doug's question. I think there is great potential for biological management of the forest, both with insects and with diseases. Look at what they have done in the Scandinavian countries by way of intensive forest management. I know we have a long way to go before we reach the level of management of the Scandinavian countries, but with the energy crisis and the potential for energy production from biomass we may have to intensify our efforts. If you look at site capacity and try to manage each site by its capacity to produce the best fibre you will see that we are going to have a lot more than one rotation age per species, because the rotation ages will have to match the site capacity. In Swastika I've harvested 30-year-old balsam fir off very rocky soil. True, I only cut out three bolts 125 cm long to a 10 cm top but if I hadn't cut it I wouldn't have had anything to cut by the time it was 35 years of age because it would have been rotten. The same applies to poplar which will also fall apart at 35 years of age on very light sandy soil. All of this fibre which is being lost to spruce budworm could be utilized if we had a market for it. And that market may be a lot closer than we think.

G. Brown: I've always been fond of the forest tent caterpillar. It's what follows it that I don't like--the spruce budworm. Apparently there is an association between the two which hasn't been too well documented yet, but I'm expecting Gord Howse and some of his associates to come through very shortly. It would appear, though, that every time you have a catastrophe it's always followed up by another one. As was pointed out yesterday by Jukka Heikurinen, you spray for one bug or one weed problem and you create another one. The tent caterpillar releases the balsam on which not only the moose but also the spruce budworm feed, so an explosion of spruce budworm invariably follows the tent caterpillar.

A.G. Gordon: Forest tent caterpillar and aspen have been living together for eons and aspen and conifers--spruce and fir--have also been living together for eons; in fact, in an evolutionary sense they probably can't do without one another. I was just talking to Al Matiece and he said what a friendly beast the forest tent caterpillar really is. I think it's about time that, except in those stands where we intend to manage aspen for high quality, we treat the forest tent caterpillar as a release agent. I'm not talking about Muskoka or the parks, but I don't believe that the forest tent caterpillar should ever be sprayed in stands where there is understory conifer. The forest tent caterpillar was there to perpetuate those conifers.

R.A. Campbell: Several times at this symposium, reference has been made to the fact that herbicide control of hardwoods increases the spread of *Armillaria mellea* root rot. It is to be hoped that undue alarm about herbicides is not generated.

R.D. Whitney: In the United States Pronos and Patton (1977) found *A. mellea*-killed red pine were highly correlated with stumps of chemically killed oak trees that were heavily invaded by *A. mellea*. To date in Ontario there is only the buildup of *A. mellea* in dead root material in herbicide-killed hardwoods as evidence of this phenomenon.

SUMMATION AND RECOMMENDATIONS

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The Table of Contents of these proceedings indicates the broad range of topics discussed at the symposium. The purpose of this chapter is to provide the reader with some overview which may stimulate not only further browsing through these proceedings, but also, perhaps, additional field action, both in management and in research.

The first challenge to the audience came early in the first paper when it was proposed that a working definition of the boreal mixedwood forest should be expressed, not in terms of forest types, but "in terms of *sites* that support or could support *good* growth of the five main component species". The reaction from some practising foresters was that such a definition did not fit the current system of working groups and was therefore not practicable. However, one could argue that for effective future forest management we need to consider the whole ecosystem of forest, soil and climate, since it is this system which requires management for wood production and other purposes.

The mixedwood forest is economically very important. It provides the highest yield per hectare of species which are highly desirable for the conifer-based industry and export market. But management is costly because of the considerable volume of undesirable species such as poplar, white birch and balsam fir which are also, after a harvest cut, very competitive; furthermore, spruce budworm is a major problem in this forest type. This complex forest requires more intensive management than it has received so far, and such management will cost money. Economically effective manipulation of this forest requires good knowledge (not just opinions) of the factors that govern growth. This ecological knowledge is needed to provide the power for successful forest management enterprises, i.e., enterprises in which a *lot* of money is spent efficiently to produce greater quantities of wood.

We are moving from an era in which forest management is concerned primarily with forest inventory and wood allocation, and some regeneration, into an era in which forest manipulation and better prediction of forest productivity are required. Combining forest inventory with site inventory should provide the information needed for planning forest land management with a view to establishing a profitable enterprise.

The key to recognizing the potential of given sites for producing species which may not be growing there at the present time lies in the use of the soil and vegetation characteristics. A two-dimensional grid of soil moisture against soil nutrient regime was used to illustrate graphically how species composition and growth may vary over a range of soils.

Forest inventories have provided information on stand yield without any reference to site conditions. However, it was shown that the estimate of gross volume is much more accurate when several variables, particularly site characteristics, are used in the prediction equations. Although we have some knowledge of the relative productivity of various sites with respect to various species, our knowledge of volume growth by site--knowledge which is required for good forest management planning--is seriously lacking.

Harvesting methods and prescriptions for regeneration need to be integrated for efficient forest management. This approach is basic to the forest management agreements recently formulated in Ontario. Harvesting methods, i.e., shortwood, tree-length, and full-tree systems, were discussed and their advantages and disadvantages were considered in relation to economic and environmental factors and silvicultural practices. The view was expressed that better utilization is not necessarily a solution to better regeneration.

Nutrient cycling is affected by harvesting practices. Preliminary results suggest that the time required to replace nutrients lost as a result of harvesting is relatively short. On the relatively rich soils of the mixedwood forest, full-tree harvesting can proceed without too much damage to site productivity, as long as physical erosion is prevented.

Fire has played an important role in the ecology of the boreal mixedwoods. It is claimed that without it the mixedwood may lose its character, its vigor and its faunal and floral diversity. Cutting operations without fire tend to increase the currently less desirable hardwood and balsam fir components. To counteract this, some authors recommended that prescribed fire be used to maintain a relatively high proportion of white spruce and black spruce.

The role of animals in the forest is also discussed. Better moose habitat with adequate food and cover can be obtained when the forest's edge is increased as a result of harvesting practices. Forestry might also benefit from a better knowledge of the role of birds in the ecosystem, particularly in relation to insect populations. A knowledge of niches critical to the maintenance of a desirable bird population (for consumption of harmful insects) may be considered in future forestry operations.

Current management practices are based on pure or mixed even-aged stands. These practices involve clearcutting (or almost) and some form of site preparation followed by planting, after which a great deal of tending is required. In spite of our efforts, pure stands become mixed to a certain degree.

For effective silviculture the forest manager needs a better understanding of stand dynamics, i.e., forest development in terms of growth, changes in species composition and susceptibility to diseases, etc. As managers we can manipulate the forest ecosystem to favor the production of valuable species. But how do we handle the increasing component of undesirable species resulting from current management techniques? Control of vegetation is important during the regeneration and juvenile stages of forest development. Various herbicides are available, but there is some controversy regarding their effect on the spread of *Armillaria mellea* via dead root material. Apparently, well trained specialists in private enterprise who apply herbicides on a regular basis are more efficient and effective than occasional users of such techniques. The economics of these methods needs to be worked out. As an alternative to herbicides, mechanical tending techniques require development, including the development and testing of new equipment.

Unfortunately, this important mixedwood forest also harbors many diseases and insects. Information on spruce budworm was updated. It was pointed out that stem decay caused important losses in relatively young balsam fir and trembling aspen, two species that are becoming increasingly abundant as old growth stands are harvested. Although some aspen clones have been found that are resistant to stem decay the majority of them are relatively slow-growing and resistant clones have not been taken into account in poplar management plans. Root rot weakens trees so that they are more susceptible to damage by wind, causes premature mortality, reduces the merchantable portion of the bole and reduces tree growth in general. Reduction of decay and root rot in all species can be achieved by shorter rotations.

What recommendations can we make as a result of this symposium? I wish to refer you to the 1979 report written by members of the Spruce-Fir-Aspen Forest Research Committee of COJFRC entitled "Forest Management and Research Needs in the Boreal Mixedwood Forest of Ontario" and edited by Weingartner and Basham. This report contains 75 recommendations which are relevant to the proceedings of this symposium. The above report is based on replies to a questionnaire sent to 32 OMNR districts and regional offices in northern Ontario, several main office sections, several research units of OFRC and a number of Canadian Forestry Service research scientists at GLFRC. The report is not just a pipe dream conceived by researchers, but contains considerable input from field managers. I shall not list all the recommendations brought forward, but it seems appropriate that readers be made more aware of the wide range of topics dealt with in the report. A summary of the recommendations follows:

1. *that an intentional mixedwood forest management philosophy for Ontario be seriously considered at policy level;*

2. *that new uses and markets be located for the currently under-utilized components of the boreal mixedwood forest;*

3. *that forest resources information be recompiled according to mixedwood management principles and that a management information system be established for young and intermediate age-class stands;*

4. *that work on stocking standards applicable to boreal mixedwood forests should be accelerated and that these standards should include growth criteria related to mixedwood site quality;*

5. *that an organized site classification of the boreal mixedwood forest in northern Ontario be developed using the existing Ontario physiographic site classification system as a basis;*

6. *that more quality information be gathered on silviculture, site requirements, and growth and yield of the main boreal mixedwood species;*

7. *that the potential importance of larch, balsam fir and hybrid poplar be determined and information be collected on their silviculture, protection, growth and yield;*

8. *that more knowledge be sought about product losses that are due to pests and about damage by diseases and pests in new stands following harvesting;*

9. *with respect to harvesting, that better information be obtained on economic losses due to under-utilization of the wood resource, on the impact of harvesting techniques, and on the maintenance of site and forest productivity;*

10. *that a thorough appraisal of the current artificial regeneration policies, particularly the "regeneration to spruce" policy, be made as part of the recommended mixedwood stand dynamics studies;*

11. *that the potential value of using modified harvest cutting as a substitute for existing regeneration techniques be investigated, and that economic and silvicultural appraisals be made;*

12. *that the economic effectiveness of natural and artificial regeneration be evaluated and the resultant species composition, as well as growth and yield, be evaluated;*

13. *that the impact of selective seed collection and seed production management on productivity be considered in artificial regeneration: the effectiveness of nursery management should be measured by field performance of outplanted stock, and planting techniques, including site prepartion, stock handling and timing of planting should be improved;*

14. *that field conditions requiring tending and the effect of herbicides on species performance, the environment, the spread of* Armillaria mellea, *and successional trends be identified;*

15. *that the economic efficiency of thinning techniques be evaluated, that standards be established for stand and site, and that new equipment be developed and tested;*

16. *with respect to forest fertilization, that diagnostic techniques be developed to identify nutrient deficiencies and that biological and economic returns be assessed;*

17. *with respect to forest protection, that economic losses from pest damage and mortality due to* Armillaria mellea *be better documented, that new approaches be taken to harvesting so as to avoid losses due to trunk rot and harvesting wounds, and that defective wood be better utilized, particularly for pulp.*

Field managers will no doubt participate in the many observations and trials which are needed. In all this it is essential not only that good records be kept, but also that documentation include descriptions of the purposes of the trials, the techniques and the basis for any conclusions reached.

The Forest Resources Branch has solicited assistance from field managers to set priorities on recommendations presented in "Forest Management and Research Needs in the Boreal Mixedwood Forest of Ontario". This in turn may lead to better formulation of the major problems, the design of appropriate research and development programs, and cooperation between field and research organizations for the purpose of achieving perceived goals.

Finally, I should like to encourage managers to make more use of models, both in the planning and in the execution of programs. We all use models in one way or another: for example, when we drive to work we have a model of the road in mind. The boreal mixedwood forest is a more complex system and we need complex models to assist us in dealing with it.

One type of model deals with relationships. An ecological classification system is available and is being developed further for northern Ontario. This system allows us to compare situations in different areas and transfer information from one area to another. It is very useful to know if information collected in Swastika applies to Geraldton or Cochrane or Dryden. Proper understanding of such a model which shows basic ecological relationships and the silvicultural equipment and methods required to obtain certain results can save us a lot of time, effort and frustration.

Another kind of model takes into consideration the fact that action in one area may produce effects in another area. We can call this a flow model. Thus, harvesting affects regeneration. Seed collection and nursery techniques affect survival and growth and the economy of the whole enterprise. We have to think beyond the responsibilities of our own projects and attempt to fit our actions effectively into the overall objectives and tasks of a large organization.

Thinking in terms of models allows us to organize our knowledge more effectively. It may also make our lives more interesting and our work as forest managers more challenging.

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